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Title	Proceedings of the 3rd international symposium for engineering education ISEE2010: Educating engineers for a changing world - leading transformation from an unsustainable global society
Author(s)	ISEE2010
Editor(s)	Byrne, Edmond P.
Publication date	2010
Original citation	Byrne, Edmond P., 2010. Proceedings of the 3rd international symposium for engineering education ISEE2010: Educating engineers for a changing world - leading transformation from an unsustainable global society. University College Cork, Ireland, 30th June - 2nd July 2010, International Symposium for Engineering Education: Cork.
Type of publication	Conference item
Link to publisher's version	http://www.ucc.ie/academic/processeng/isee2010/proceedings.html Access to the full text of the published version may require a subscription.
Item downloaded from	http://hdl.handle.net/10468/379

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University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

Proceedings of the 3rd International Symposium for Engineering Education ISEE2010

University College Cork, Ireland

30th June – 2nd July 2010

ISEE 2010

Educating Engineers
for a Changing World

Leading transformation from an unsustainable global society

ISSN: 2009 3225

UCC
Coláiste na hOllscoile Corcaigh, Éire
University College Cork, Ireland

Welcome
Address

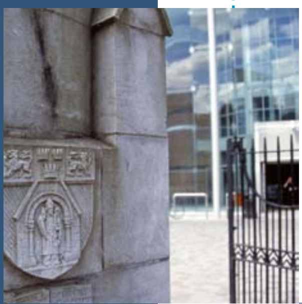
On behalf of the ISEE 2010 organisational team, we are delighted to welcome you to University College Cork for the 3rd International Symposium for Engineering Education. ISEE2010 is a truly national and international event. The Symposium features papers from eight of the nine universities throughout Ireland as well as from several third level institutes and from industry. In addition, there are papers from throughout Great Britain, from the United States of America, Canada, the United Arab Emirates, Australia, the Czech Republic, Portugal, Denmark, Finland, Germany, India, Brazil and South Africa. We would like to warmly welcome over 130 delegates from almost two dozen countries across all six continents to UCC for what we hope will be a memorable and worthwhile visit.

The principal theme of ISEE2010 is 'Educating Engineers for a Changing World – *Leading transformation from an unsustainable global society'.* The Symposium includes papers (delivered in both poster and oral format) on this theme and all the sub themes of the Symposium including teaching and embedding sustainability throughout the curriculum, active learning approaches including problem based learning and CDIO, achieving learning outcomes and student understanding, industry perspectives, engineering ethics, global and future perspectives, student recruitment, fourth level education and IT applications.

Each of the papers selected for ISEE2010 have been subjected to a thorough peer review process by our specially invited International Advisory Panel (IAP). The IAP consisted of 62 expert academics across 13 countries. We would like to thank each of them for generously providing their time and expertise in carefully reviewing all the submitted papers and for providing constructive comments to respective authors. This has resulted in an even higher level of submission quality. Indeed, several authors have expressed their gratitude at the constructive and insightful feedback they received, which enabled them to improve their papers between initial and final submission stages.

We are especially delighted to welcome four outstanding keynote speakers to the Symposium. Our three academic guest speakers are not just global leaders in engineering education but are also true global visionaries. Both David Shallcross and David Wood are international giants in engineering education, in particular in the field of chemical engineering. Cheryl Desha is a widely published environmental engineer whose reputation in the field of sustainable development in engineering education is deservedly far reaching and John Mullins, our industry speaker, is a UCC engineering graduate who possesses a well developed vision of where his organisation, country and profession needs to be, complimented by a corresponding passion to see it realised, and to do so fast. We would like to especially thank John

Whether you are a new arrival to UCC for ISEE2010 or a serial returnee, I join with all the ISEE2010 Organisation Team in wishing you a warm Cork welcome!



and Bord Gáis Éireann for their generous sponsorship of the Symposium. As main sponsors Bord Gáis provided us from an early stage with the certainty and support to plan ahead and enable us realise our ambitions for this event. The Bord Gáis team, including Caroline O'Connor and her colleagues have been a pleasure to work closely with for their insights, professionalism and drive.

We would like to welcome four major professional engineering institutions to ISEE2010; namely (in alphabetical order) *Engineers Australia, Engineers Ireland, the Institution of Chemical Engineers* (IChemE) and the *Institution of Mechanical Engineers* (IMechE), and in particular their respective representatives. The willingness of these institutions to engage in ISEE2010 has been hugely encouraging, though not surprising given the leadership that each of these great institutions are showing on both national and international stages. We would especially like to thank Engineers Australia and Alan Bradley for committing to such a long distance commute to share in the conversation we are having at ISEE2010. Their presence here is a hugely powerful statement. Also, thanks to Engineers Ireland and its Director General John Power, who has been personally very supportive of the endeavour, and to the IChemE, who have been exceptionally supportive at all levels from the beginning. Their visionary outlook as epitomised by the IChemE's Roadmap for the 21st Century has in my opinion, scarcely received due credit for the recent and ongoing surge in interest in chemical engineering among school leavers throughout the UK. The leadership and global vision shown by its sister organisation, the IMechE is no less substantial. We look forward to the Professional Institutions Forum and I'm sure it will result in a lively, informed and insightful discussion with some potentially useful outcomes.

We are delighted too to welcome Cheryl Desha of Australia's *'The Natural Edge Project',* for the international launch of her publication *'Engineering Education & Sustainable Development - A Guide for Rapid Curriculum Renewal'*. Cheryl will host a Delegate Workshop which will focus on the Symposium theme from a curriculum perspective and this feature promises to be one of the true highlights of the Symposium.

On a more local basis, we'd like to also thank the widespread support we've received throughout UCC in hosting this event. Professor Patrick Fitzpatrick, Head of the College of Science, Engineering and Food Science and Dr Michael Creed, Head of the School of Engineering could not have been more supportive of the endeavour, nor indeed could Professor Grace Neville, Vice President for Teaching & Learning. Thanks also to all our UCC colleagues who agreed to participate on the IAP.

Finally, and on a personal level, I would like to thank my colleagues on the ISEE2010 Organisation Team. As a team, we've worked assiduously over the past 20 months to piece this Symposium together. To my friend and colleague Dermot Brabazon of DCU, who is the originator of the ISEE series, and who first mooted the idea of it coming to UCC, to my UCC friends and colleagues Kevin Cronin and John Fitzpatrick, who have been exceptional team mates and workers, and without whose support this simply could not have happened, and to John Barrett, whose craft and skill is evident through all the IT paraphernalia, including the excellent website and associated design material. I'd also like to thank the ISEE2010 support team, who are helping to make sure ISEE2010 runs smoothly over the next couple of days and all our colleagues in Process & Chemical Engineering and the School of Engineering for their support. Finally, there is one person without whose input this event would simply not be half the event it is, and that is Anne-Marie McSweeney, our Symposium Manager. Anne-Marie's work-rate, expertise, and attention to detail have been absolutely incredible. Her input has been doubly exceptional when considering that she took on this role in addition to her ongoing role. With the arrival of ISEE2010 now upon us, Anne-Marie and her family are looking forward to another very special arrival in the near future; we wish her and her growing family the very best ahead.

Whether you are a new arrival to UCC for ISEE2010 or a serial returnee, I join with all the ISEE2010 Organisation Team in wishing you a warm Cork welcome and a hope that you will find the next couple of days to be a stimulating, challenging and energising experience as you discuss, share, listen and deliberate on issues related to engineering education and its place in the changing world that is the 21st Century.

Edmond Byrne
Chair ISEE2010

ISEE2010

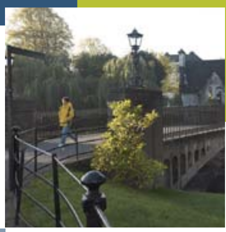
Welcome to the third instalment!

"The International Symposium for Engineering Education series encourages the sharing of ideas, innovation and best practice among those involved in the field of engineering education. This symposium was first held in Dublin City University in 2007 and again in 2008. As well as having diverse international participation, attendance has been broad including those involved in teaching engineering curriculum including science and maths at higher level, those conducting research in engineering education, support staff and research students in engineering Schools/Departments. Exciting new tools, such as development in Virtual Learning Environments (VLE) and Reusable Learning Objects (RLOs), for the educator to meet the changing needs of student learning are presented and discussed at this symposium.

This year the conference is being held in University College Cork on the 1st and 2nd July 2010. The theme of sustainable engineering education is a topical and appropriate focus of this year's symposium. Session topics include Industry Perspectives, Global Perspectives, Engineering Ethics & Sustainability in the Curriculum, Student Understanding, Future Perspectives, Student Engagement & Learning Outcomes, Teaching Sustainability, Problem Based Learning (PBL), Innovation & Information Technology, and Developing Skills & Learning Outcomes. I take this opportunity to thank the support of the conference organisers, paper reviewers, supporters and sponsors who have made the running of this series possible. In particular, I would like to thank the organisers of this year's symposium: Edmond Byrne, Kevin Cronin, John Fitzpatrick, Anne-Marie McSweeney, John Barrett; and sponsors which include Institution of Mechanical Engineers, Engineers Ireland, NDLR and Bord Gáis. The next location for the ISEE series in 2012 will be the University of Sheffield."

Dermot Brabazon
Co-Chair ISEE2010 & ISEE Series Originator

Leading Transformations - Not a Simple Task!

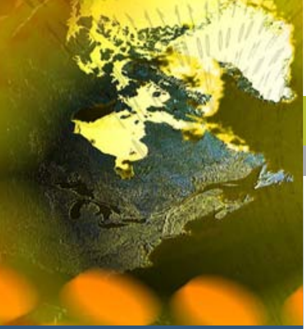


The theme of ISEE2010 '**Educating Engineers for a Changing World** - *Leading transformation from an unsustainable global society*' strikes a particular resonance at this current time as we are increasingly being forced to reflect on both the complexity and the fragility of the world and society that we inhabit.

Enormous strides for the betterment of humankind have been realised over the past couple of centuries. Engineers have been at the forefront of this, designing transport and energy systems, electronics, communications, medicines and spearheading improved provision of food and water for an ever expanding global population. The result is a highly complex and interconnected global 21st Century society.

More recently, we have been presented with ever increasing evidence of the fragile nature of the economic, societal and ecological systems that we are part of. These are symptoms of unsustainable patterns of behaviour that can ultimately tip the meta-systems that make up our broader environment from one set of seemingly predictable conditions to another altogether different and more erratic set. This is itself a feature of complex systems. Of course all human and natural systems are complex, though complexity is not in itself trivial, despite its common usage. Complex systems can for example, exhibit what is known as emergent behaviour, that is they are prone to behave in ways which cannot be predicted by models, even when all input parameters are fully taken into account. In such instances, expected operational behaviour is confounded. This is as a result of the whole essentially being greater then the sum of its constituent parts. In this way, Murphy's Law and the Law of Unintended Consequences can be envisaged as constant, if unwanted companions, particularly for stressed systems close to bifurcation of tipping points.

Even here, while the proximate cause or indeed timing of a catastrophic event or sudden change to a significantly different pattern of behaviour cannot be precisely determined in advance, whether this be collapse in the sub-prime US housing market, an earthquake in Haiti, a volcano in Iceland, a global flu pandemic, failure at an oil rig, at an industrial process site or a nuclear power plant, an extreme weather event, demand versus supply for commodities such as energy, water or food, the result can have profound and unforeseen consequences. The answer to this for engineers is of course not to despair nor even to simply treat complex systems as more manageable ones by making some assumptions in order to model these systems as merely complicated ones, on the basis that these models work well most of the time (i.e. during 'normal' operating conditions). Rather, if we wish to understand such



systems better, it behoves us to pay more attention to the whole system outputs, by 'listening' more closely to what the system is telling us and paying more heed to experiential and local learning. In such situations therefore, a top down whole systems approach can help better understand the system performance rather than merely a bottom up analysis.

It is in this context that engineers must look forward to the 21st Century, and all its emerging and emergent issues; and it is in this spirit that the United States National Academy of Engineering in its 2004 publication 'The Engineer of 2020: Visions of Engineering in the New Century' called for engineering curricula to be reconstituted "to prepare today's engineers for the careers of the future, with due recognition of the rapid pace of change in the world and its intrinsic lack of predictability".

Complex systems are characterised too by extremely high levels of connectivity among its constituent parts. With a continuing expanding global population and an even greater rate of increase in consumption, and set against a backdrop of finite available resources, the challenge for the 21st Century engineer must be one of helping transform society to one which can maintain and improve the quality of life of the greatest number of people within the earth's carrying capacity.

It is a big ask, perhaps the biggest we've faced to date. It is also one which will require engineers' engagement with other professions, disciplines and expert peer groups as we try to understand and hence govern (as opposed to 'control') the complex manmade and natural systems that we are part of. Such problems clearly demand a more nuanced, smarter approach than that presented by the mechanistic Cartesian inspired world that has thus far by and large, served us extremely well.

However, if we as engineers are to play a lead role in this necessarily multi-disciplinary task, then we'll also need to broaden our horizons and skill sets beyond those of the mere technological 'guns for hire', whose horizon stretches no further than to solve well defined (albeit highly complicated) problems. In truth, we have the ability and capacity to offer a lot more than this. We need to raise our ambition. With the right approach we can offer leadership in helping both frame and resolve the relevant complex problems that surround us.

I'd like to therefore welcome you to UCC for ISEE2010, in the hope that it will provide a platform for debate, discussion and reflection and above all, an enlightened conversation on what type of approach we might envisage to ensure engineering education and practice are fit for purpose from the second decade of the 21st Century and beyond. While the answers to these questions will be many and varied, we can all acknowledge the special responsibility on us as professional educators and baton carriers.

The type of engineer outlined above certainly requires a new approach to educating engineers to that which has been employed in the past. The building blocks upon which this new engineer can be constructed provide an agreeable confluence with current best practice in higher level educational practice and indeed with industry needs. These are also the issues which are explored and reflected upon throughout this Symposium; the learning outcomes approach, problem based learning, the Conceive-Design-Implement- Operate (CDIO) approach, peer evaluation, group project and design work, entrepreneurship and innovation, multi-disciplinary studies, deep learning, self awareness and reflective practice, professional ethics, communication and presentation skills.

It is delightful to see both the breadth and quality of the papers being presented on these issues, both orally and in poster format at ISEE2010, demonstrating a strong willingness of engineering educators across the globe to be both innovative and reflective in their own practice. At the core of each and every presentation is a singular enthusiasm for creating a teaching and learning experience with and for our students which will in turn, enlighten and enthuse following generations of engineers. This is indeed a noble pursuit, and one which requires both time and dedication. As top engineering academic, educational scholar (and ISEE2010 IAP member) Richard Felder remarked in 2004; *'Doing world class research is essentially a full time job. So is doing outstanding teaching.'*

The importance of inspiring a cohort of highly motivated engineering graduates through exposure to world class (student-centred) educational experience cannot be overstated. It is instrumental in adding real value to our profession, to the economy and its environment and in helping create a smart and innovative global society. I wish you an invigorating, challenging, insightful and inspirational few days ahead.

Edmond Byrne
June 2010

ISEE2010

Organising Committee

Dr Edmond Byrne

CEng, MIEI, MIChemE

Symposium Chair

Edmond Byrne has a Chemical Engineering degree (2005) and an MSc from University College Dublin, as well as a PhD (2001) and MA in Teaching & Learning in Higher Education from UCC. He lectures in Process & Chemical Engineering at UCC and is founder and programme director of UCC's Certificate/Diploma in Process & Chemical Engineering and PG Dip/MEngSc in Pharmaceutical & Biopharmaceutical Engineering. He is chair of UCC's College of Science Engineering & Food Science Teaching & Learning & Student Experience Committee. His research interests include the study of particulate operations involving breakage and growth and chemical engineering education, with a particular interest on embedding sustainability in engineering education.

Dr Dermot Brabazon

CEng, MIEI, MIMechE, MIoM

Symposium Co-Chair

Dermot Brabazon completed his undergraduate degree in Mechanical Engineering at University College Dublin in 1995 and his PhD in 2001. From 1995 to 2000 he worked with Materials Ireland solving industrial related materials problems. In February 2000, he joined Dublin City University (DCU) as a lecturer in the School of Mechanical and Manufacturing Engineering and was appointed as senior lecturer in the School in 2007. He was appointed as Deputy Head of School later in 2007 and in 2009 as Associate Dean of Research in the Faculty of Engineering & Computing. He founded the International Symposium for Engineering Education which was first held in Dublin City University in 2007.

Dr John Fitzpatrick

CEng, MIEI, MIChemE

Symposium Co-Chair

Dr. John Fitzpatrick is currently a Senior Lecturer in Process & Chemical Engineering at University College Cork (UCC). He has a PhD in Agricultural / BioProcess Engineering from Texas A&M University and an MA degree in Teaching & Learning in Higher Education from UCC. He teaches modules in environmental protection, sustainability, bioprocess engineering, thermodynamics, unit operations and particle technology. His main research interests are in the areas of particle and powder technology, sustainability and the scholarship of teaching and learning.

Dr Kevin Cronin

Symposium Co-Chair

Dr. Kevin Cronin is by degree a Mechanical Engineer and works as a lecturer in the Department of Process & Chemical Engineering at University College Cork. He has held that position since 1995. His main teaching area is in Mechanical Design of Process Equipment with a secondary interest in Process Safety. He has published a number of papers in the literature of Engineering Education and has been involved in projects to develop teaching software and to deliver modules remotely by computer. His primary research field has been in the probabilistic simulation of the thermal processing of biological materials and stochastic modeling of particulate systems.

Anne-Marie McSweeney

Symposium Manager

Anne-Marie McSweeney graduated with a BA (Joint Hons) in French and Philosophy from UCC in 1991 and a Graduate Diploma in Business Administration from UL in 1992. Having worked for 3 years as a Database Administrator with the UCC Foundation, she embarked on a career in Marketing, first with publishing companies, Oak Tree Press, Dublin and Euromoney Plc, London and then in conferencing with SMi Group and IF Executives Ltd., both in London. Anne-Marie returned to Ireland in 2002 and started working with the Department of Process & Chemical Engineering, where she has been Senior Executive Assistant ever since.

John Barrett

IT / Multimedia

John Barrett works in technical / IT support in the Department of Process & Chemical Engineering, University College Cork. His initial qualifications from Waterford Institute of Technology were in the area of Biotechnology. He later developed an interest in IT / Multimedia and completed an MSc in Multimedia Technology in the Department of Computer Science, University College Cork in 2007.

The MSc project involved the development of an online Heat Exchanger Experiment for use in teaching. John maintains an interest in the use and development of online teaching tools.

ISEE2010

Sponsors and Affiliates

ISEE2010 would like to acknowledge and sincerely thank Bord Gáis Éireann for acting as main sponsors for the Symposium. We would also like to thank all the other sponsors and affiliates of ISEE2010 (shown below), including the four peak Professional Engineering Institutions who have supported this event.

Main Sponsors

BORD GÁIS

Other Sponsors & Affiliates

ENGINEERS AUSTRALIA

Institution of MECHANICAL ENGINEERS

IChemE Institution of Chemical Engineers

ENGINEERS IRELAND

Fāilte Ireland National Tourism Development Authority

irelandinspires.com

epa Environmental Protection Agency An Ghníomhaireacht um Chaomhnú Comhshaoil

HELION HYDROGEN POWER

Bord Gáis was founded in 1976 to develop the natural gas industry in Ireland following the discovery of natural gas off the south coast. It is a commercial state body operating in the energy sector. The company employs just over 1,000 staff and is headquartered in Cork City, Ireland.

Today, Bord Gáis is a leading energy provider, serving c. 640,000 gas users in 152 population centres in Ireland. Bord Gáis owns and operates over 13,100km of gas pipelines, including two sub-sea interconnectors with Scotland from where Ireland gets over 93% of its gas supplies.

Taking advantage of liberalisation in the energy markets, Bord Gáis entered the business electricity supply market in 2001. In February 2009, the company entered the residential electricity sector and by year-end had gained over 300,000 additional customers thus increasing its share of the total electricity supply market to 12%. It is constructing a 445MW gas-fired power station at Whitegate in Co. Cork, operates 218MW of wind generation and is developing gas fired peaking plants and a significant portfolio of wind farm developments in various locations throughout the country.

Sustainability

Addressing climate change is a clear and growing political and economic priority. Bord Gáis' concentrated actions in this area will bring more efficient and lower-carbon assets into the power generation mix in Ireland and will enable householders to reduce their carbon footprint as well as their energy costs.

Corporate Social Responsibility

There are four main strands of the Company's Corporate Social Responsibility approach: Marketplace, Workplace, Community and Environment.

In the Community, Bord Gáis works with local communities to ensure that our construction projects in the locality cause minimum disruption. Our company sponsors popular sporting, cultural and educational events. Bord Gáis also plays its part in protecting the most vulnerable in society, leading initiatives that support a multitude of volunteer and community organisations.

The Way Forward

Bord Gáis has made a strong economic and social contribution to Ireland over its 35 year history. It has built a modern gas infrastructure which has met the needs of the country and brought the benefits of clean, natural gas to hundreds of thousands of customers.

The business strategy currently being aggressively implemented has changed the company dramatically. Bord Gáis is an exciting, ambitious enterprise focussed on achieving its goals. Bord Gáis is a full service energy company, supplying gas and electricity services to 1 million customers throughout Ireland and will continue to build its position in the energy market over the coming years.

Fáilte Ireland provides strategic and practical support to develop and sustain Ireland as a high-quality and competitive tourist destination. We work with the tourism industry in areas including business support, enterprise development, training and education, research, marketing and regional development.

With a dedicated team working across five regions, Fáilte Ireland offers tourism professionals and service providers a wide range of support services at local, regional and national levels. Fáilte Ireland works in partnership with Tourism Ireland (the agency responsible for marketing the island of Ireland overseas as a holiday destination) and the Northern Ireland Tourist Board (responsible for tourism development and marketing in Northern Ireland).

We also lead an extensive domestic holiday campaign via www.DiscoverIreland.ie, which features comprehensive information and listings for Irish accommodation, activities, events, tourist attractions and Irish holiday special offers.

Effective management of the environment is increasingly science-driven. Through our research and development programme, the Environmental Protection Agency is generating the knowledge and expertise needed to protect and manage Ireland's environment.

The EPA research programme for the period 2007-2013 is entitled Science, Technology, Research and Innovation for the Environment (STRIVE). The purpose of the programme is to protect and improve the natural environment by addressing key environmental management issues through the provision of world-class scientific knowledge generated through a vibrant, competitive programme of research developed supported and co-ordinated by EPA.

Projects range in scale from desk studies and scholarships up to large-scale multi-annual projects. Research is carried out by researchers in colleges, state research organisations, companies and individuals.

Research is funded under the following core topics:

- Air Quality
- Biodiversity
- Environment & Health
- Environmental Technologies (including the Cleaner Greener Production Programme (CGPP))
- Climate Change
- Land-Use, Soils and Transport
- Socio-Economics
- Water Quality
- Waste and Resource Management.

Industrial actor in the hydrogen sector, HELION is specialized in the development, qualification & commercialisation of CO2-free solutions to produce hydrogen by water electrolysis, power by fuel cell systems & cutting-edge energy storage.

HELION is a major industrialist specialising in hydrogen energy. It develops and commercialises water electrolysis solutions for hydrogen production, as well as electrical and heat energy production systems based on fuel cells.

Relying on its expertise in the design of test benches for its own requirements, HELION has developed in partnership with engineering universities, an educational test bench that offers the best compromise between safety, students autonomy and pertinence of results.
The educational test bench employs a PEM type fuel cell supplied with hydrogen and air and has a power of 1 kWe. It is designed to operate without specific equipment in the operating premises, and provides a practical work autonomy of around 4 hours.

This practical work permits a better understanding of the physical phenomena in play such as temperatures, flow rates, pressures, stoichiometry …via the didactic package that includes an instrumented bench, professional analysis and simulation tools and forward compatible pedagogy.

ENGINEERS AUSTRALIA

Engineers Australia is the national forum for the advancement of engineering and the professional development of our members. With more than 85,000 members embracing all disciplines of the engineering team, Engineers Australia is the largest and most diverse professional body for engineers in Australia. Our chartered engineers are regarded as trusted professionals not only in Australia, but worldwide.

We seek to:

- Advance the science and practice of engineering
- Cultivate lifelong learning by our members
- Promote the contribution of the profession as widely as possible
- Champion professional and ethical conduct
- Welcome all those who wish to practise engineering
- Allow members' aspirations to flourish, and learn from their creativity and innovation
- Celebrate excellence in engineering outcomes
- Draw inspiration from our engineering heritage
- Sustain the integrity of the profession
- Take the lead in advocacy of the profession.

IChemE

Institution of Chemical Engineers

The Institution of Chemical Engineers (IChemE) is an international professional membership organization for people who have an interest in and relevant experience in chemical engineering. IChemE is the hub for chemical, biochemical and process engineering professionals worldwide. IChemE is the heart of the process community, promoting competence and a commitment to sustainable development, advancing the discipline for the benefit of society and supporting the professional development of members.

Founded in 1922 as a professional institution for chemical and process engineers, IChemE has grown to its current status of a 30,000 international membership across more than 113 countries.

As well as promoting the advancement of chemical engineering science and practice within the profession, IChemE aims to increase the public recognition of chemical engineering, both in terms of what chemical and process engineers do and the benefits that their work brings to society. IChemE actively develops and raises standards in education with the accrediting of 60 higher education establishments internationally (over half outside the UK).

ENGINEERS IRELAND

With over 24,000 members from every discipline of engineering, Engineers Ireland is the voice of the engineering profession in Ireland. We have been representing the engineering profession since 1835, making us one of the oldest and largest professional bodies in Ireland. Our more than 24,000 members come from every discipline of engineering, and range from engineering students to fellows of the profession.

We continue to build strong educational relationships with Irish universities and institutes of technology, primarily through our role in the accreditation of their engineering programmes.

We also run educational outreach initiatives such as the STEPS to engineering programme to get primary and secondary level students interested in engineering and its role in society.

Institution of MECHANICAL ENGINEERS

The Institution of Mechanical Engineers (IMechE) is the fastest growing professional engineering institution in the UK. Our 80,000 members work at the heart of the country's most important and dynamic industries.

With a 160-year heritage supporting us, today's Institution is a forward-looking, campaigning organisation. By working with leading companies, universities and think tanks, we create and share knowledge to provide government, businesses and the public with fresh thinking and authoritative guidance on all aspects of mechanical engineering.

We truly believe we can improve the world through engineering. So the Institution finds and nurtures new talent, helping engineers build their careers and take on the challenges that, when solved, will make a difference to all of us.

In the UK, engineering has achieved great successes, but in a quiet way. We're looking to shout about the achievements of our members and the industry, taking a positive, inspiring message into schools and out into the media. By being independent of both government and business, and avoiding strategic relationships with single-issue bodies or pressure groups, we can deliver genuinely impartial advice in a passionately committed manner.

As an Institution, we focus on four principal themes which affect and are affected by our engineers:

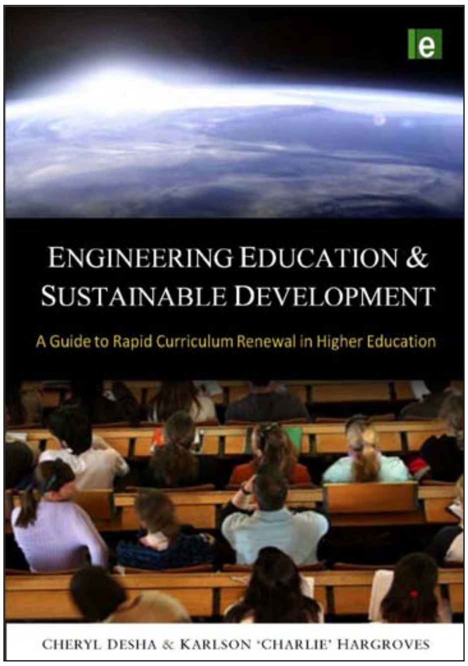
- Energy
- Environment
- Transport
- Education

Map
of UCC Campus

Below is a map of the UCC main campus, with all ISEE2010 venues identified. UCC is located on the western edge of Cork city, about a 15 minute walk from the centre along Western Road. The main campus lies just south of the southern channel of the River Lee (Cork city centre is located on an island) which runs through the grounds and is overlooked by the Glucksman Gallery. The campus is a 15 minute (10 km) taxi drive from Cork Airport, which is located just south of Cork city. The main university entrance (pedestrian) is on Western Road, adjacent to the bridge at the top right hand side of the map. The main vehicular entrance (for taxis, etc.) is along College Road (between the Electrical and Civil Engineering buildings). There are also other pedestrian entrances on College Road and on Donovan's Road.

Opening Welcome Reception & Book Launch

Wednesday, 30th June 2010 @ 8.00pm,
Glucksman Gallery, UCC



University College Cork welcomes you to the third International Symposium for Engineering Education (ISEE2010). We are honoured to welcome a distinguished array of special guests, headed by the Lord Mayor of Cork (or representative), the President of University College Cork, Michael B. Murphy and fittingly, for his last official function on his final day of office, the President of UCC Students Union and graduate of the School of Engineering, Eoin Hayes BE.

We are also delighted to incorporate the international launch of the publication 'Engineering Education & Sustainable Development 'A Guide for Rapid Curriculum Renewal" at this evening's reception, where we are joined by co-author Cheryl Desha of the Australian based The Natural Edge Project.

The following provides an overview of this publication:

'A Guide for Rapid Curriculum Renewal in Higher Education'

As the title suggests, the issue of engineering education and how it can systemically embed Sustainable Development knowledge and skills is now a major consideration for engineering educators globally. In a rapidly changing market and regulatory environment, this book will provide practical support for the millions of engineering educators around the world who are grappling with how programs of study can be strategically and systematically renewed to address emerging 21st Century challenges. By collating, synthesizing and contributing to the body of knowledge on the process of embedding sustainability within curriculum, the authors hope to address key barriers to curriculum renewal and in doing so, help to build momentum for a rapid and large scale transition in the engineering education sector.
As the engineering education for sustainable development (EESD) field is still emerging, and as early career academics in the topic area, the authors have relied on the extensive experience and wealth of knowledge within a network of more than 40 researchers, practitioners and students from more 14 countries, to ensure that the latest research and opportunities are communicated, while being sufficiently pragmatic and realistic with regard to the scale of the challenges, and existing inertia within the higher education system and engineering education fraternity.

Lead Authors and Editors:

Cheryl Desha, Education Director, The Natural Edge Project (hosted by Griffith University and the Australian National University); Lecturer, School of Engineering, Griffith University.

Karlson 'Charlie' Hargroves, Director, The Natural Edge Project (hosted by Griffith University and the Australian National University); Research Fellow, Science, Engineering, Environment and Technology Group, Griffith University.

Publisher: Earthscan

ISEE2010
Gala Dinner

The ISEE2010 Gala Dinner takes place in the historic surrounds of UCC's Aula Maxima on the evening of Thursday 1st July. Dinner will be preceded by a Welcome Drinks Reception in the adjacent Staff Common Room.

This promises to be the social highlight of ISEE2010, as we invite you to enjoy good food & drink, company & craic, in the convivial setting of the Aula Max, overseen by UCC's past presidents and an august tome or two. You might even like to sample some 'ISEE2010 Special Brew', our specially produced Symposium beer, which has been freshly brewed in UCC's own microbrewery especially to celebrate the occasion of your visit!

The special guest speaker for this evening is Mr John Mullins, CEO of Bord Gáis and a graduate of Engineering at UCC. John will be introduced by ISEE2010 co-Chair Dr Kevin Cronin.

7.30 pm Welcome Drinks Reception *(Staff Common Room, North Wing, Main Quadrangle, UCC)*

8.00 pm Gala Dinner *(Aula Maxima, North Wing, Main Quadrangle, UCC)*

Queen Victoria's Coat of Arms dating from 1837

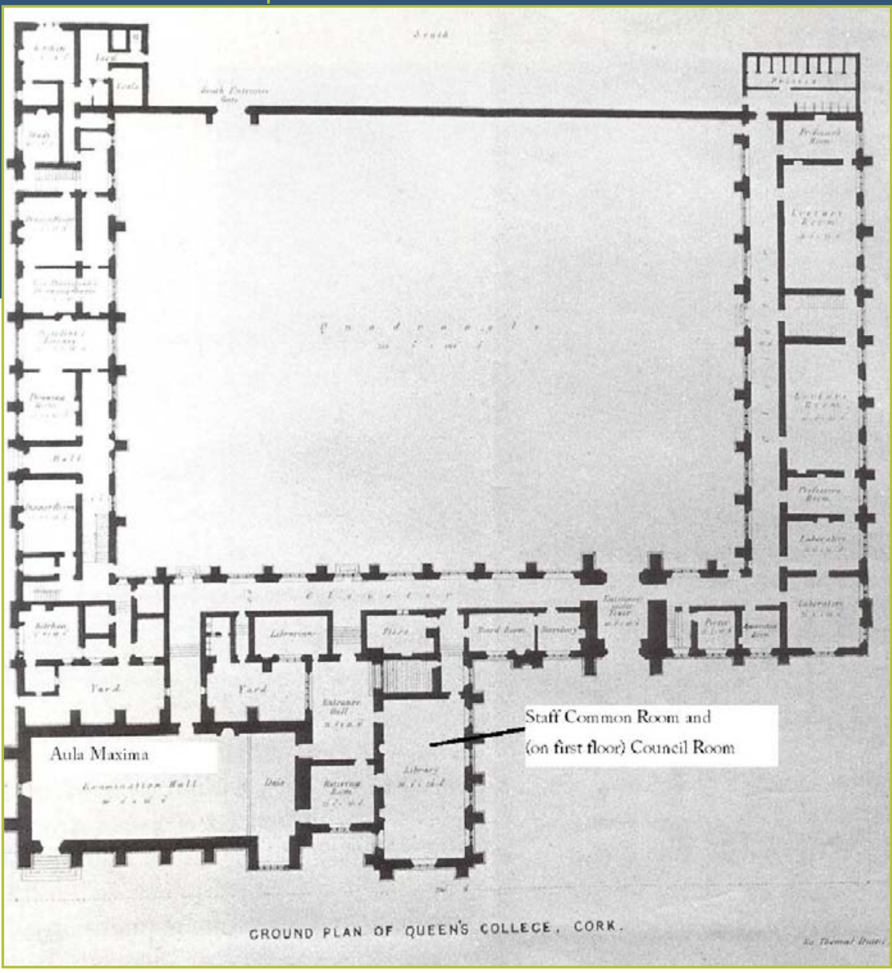
The Aula Maxima; Embedded in History

The Aula Maxima, though modelled on a late medieval banqueting hall, still finds use for its original purpose as a 'magnificent Examination Hall', over one hundred and fifty years after its inauguration on 7th November 1849[1]. Queen Victoria had seen both it and the main Quadrangle building almost three months earlier, and it was described at that time in the *Examiner* newspaper as *'one of the most magnificent rooms in Ireland'.*

The room is overlooked on the east side by a magnificent memorial stained glass window (1866) of George Boole, the first professor of mathematics at the university (1849-64), and he is flanked by Aristotle and Euclid. On the opposite wall hang portraits of all past presidents of UCC.

Indeed, the entire Quadrangle was opened on that November day in 1849 as a physical manifestation of the newly founded Queen's College Cork (QCC). The site of the university itself was chosen as *'a cheerful and healthy site, with a good approach',* and in the words of its architect Sir Thomas Deane *'most beautiful for a public building'.* The site was also considered in keeping with the aesthetic sensibilities of the city's citizens where there *'is more attention paid to the promotion of science and the encouragement of fine arts by the inhabitants, than what is generally met with in provincial towns'.* Deane's original plans featured a fourth side to the Quad, which was never built, incorporating a wall and gate across its south end (see plan).

1 Murphy, J.A., 1995. The College A History of Queen's/University College Cork 1845-1995, Cork University Press.



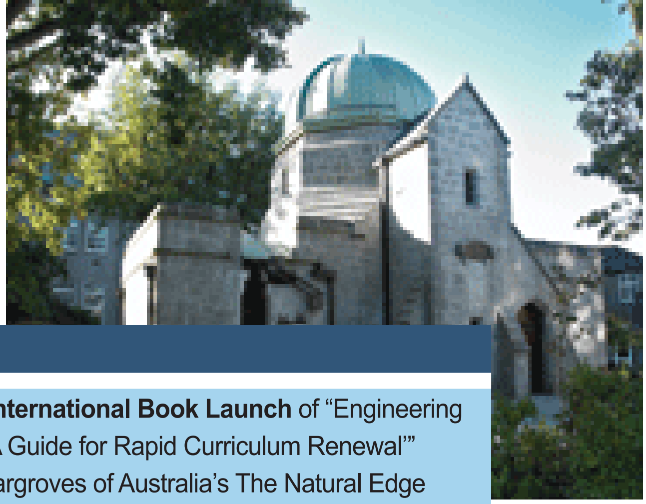
Deane's ground plan of main quadrangle, UCC

QCC had come into existence just four years earlier, along with its sister Colleges, Queen's College Belfast (now QUB) and Queen's College Galway (now NUIG) following the successful passing at Westminster of the Colleges (Ireland) Bill in July 1845, in what was *'the first venture by the state into the university area'*. These were to be provincial colleges based on the 'Gower Street' model of London University - *'non-sectarian, non-residential, low-fee, systematic lecturing'* institutions, rather than based on the Oxbridge tutorial system. This was strongly supported by the likes of influential writer and journalist Thomas Davis, as someone who assiduously promoted understanding, conciliation and union among all of Ireland's traditions, seeing education as the ultimate vehicle for this. For him therefore, *'the "mixed education" spirit of the act was in harmony with the fraternal national philosophy.'*

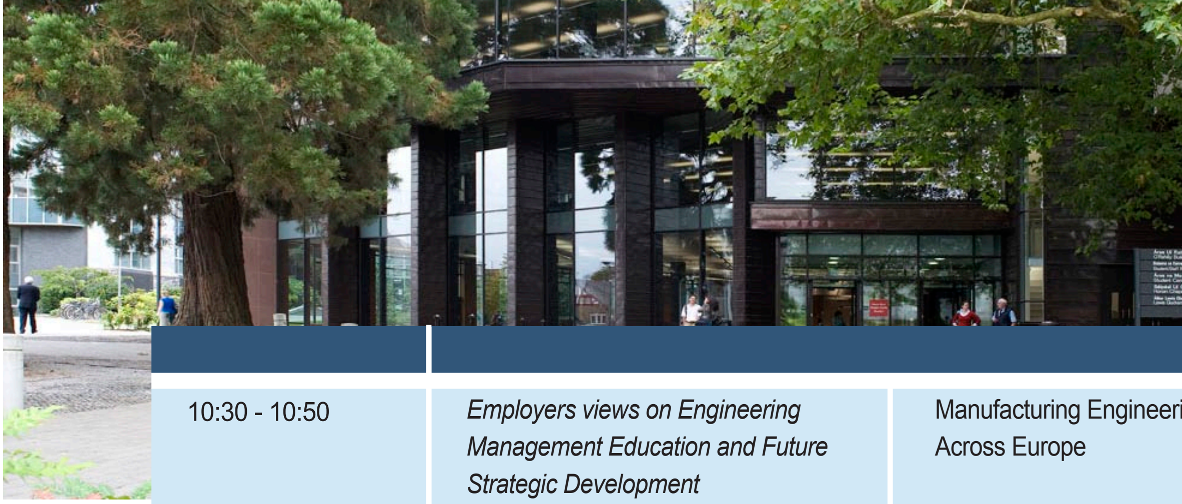
Each of the Colleges were subsequently consolidated as the Queen's University in Ireland with a common Chancellor when its charter was incorporated a century and a half ago on 3rd September 1850.

When the college opened the previous November, it had enrolled 115 students, of which ten were in engineering. Things quickly progressed however, and by 1863-64 there were 48 engineers enrolled, buoyed by *'various building and construction developments in imperial parts like India and to the demands of the new railway age at home'*. This was at a time when *'the numbers in Belfast and Galway remained in the ten to fifteen range'*. Clearly numbers continued to increase over the following decades, and in 2009-10 there were 564 undergraduate engineering students at UCC.

ISEE2010
Programme



	Wednesday, 30th June 2010	
19:45	**Symposium Opening Reception and International Book Launch** of "Engineering Education & Sustainable Development 'A Guide for Rapid Curriculum Renewal'" by Cheryl Desha and Karlson 'Charlie' Hargroves of Australia's The Natural Edge Project (TNEP). Special Guests of Honour include: The Lord Mayor of Cork, The President of University College Cork, Dr Michael B. Murphy, The President of the UCC Students Union, Mr Eoin Hayes BE Sponsored by Bord Gáis *(The Glucksman Gallery, UCC)*	
	Thursday, 1st July 2010	
08:40 - 08:50	**Introduction by Chair - Dr Edmond Byrne** *(Boole 1)*	
08:50 - 09:00	**Welcome Address & Best Paper Awards Presentation** Prof. Patrick Fitzpatrick (Head of College of Science, Engineering & Food Science, UCC) *(Boole 1)*	
09:00 - 09:30	**Keynote 1 - John Mullins (Bord Gáis, CEO)** *Industry Perspectives on Engineering Education (Boole 1)*	
09:30 - 11:10	**Session 1 (Boole 1): Industry Perspectives Chair: Dr Michael Creed**	**Session 2 (Boole 2): Global Perspectives Chair: Dr Kevin Cronin**
09:30 - 09:50	*The under-recognised value of creativity in the workplace roles of Engineering doctoral graduates* **Karen Adams, Margie Ripper, Anthony Zander and Gerry Mullins**	*Heat and mass transfer in the long rains: doing engineering under a mango tree* **Colin Pritchard**
09:50 - 10:10	*Educating EirGrid's Power System Engineers to facilitate a sustainable future - a partnership of Academia and Industry* **Patricia Wade and Adele Sleator**	*Cross-Departmental Initiatives for a G Global Dimension in Engineering Education* **Esat Alpay, Anthony Bull and Alison Ahearn**
10:10 - 10:30	*Practical skills and techniques for the transition to a sustainable future, a case study for engineering education* **Brian Dwyer and Edmond Byrne**	*Implementing English Medium Instruction (EMI) for Engineering Education in Arab world and twenty first century challenges* **Abdalmonem Tamtam, Fiona Gallagher, Sumsun Naher and Abdul Ghani Olabi**



10:30 - 10:50	*Employers views on Engineering Management Education and Future Strategic Development* **Peter Gibson and Peter Childs and Srichand Hinduja**	Manufacturing Engineering Education Across Europe **George Barrow, Robert Heinemann**
10:50 - 11:10	*Incorporating A 5S Structured Approach To The Planning And Delivering Of A Final Year Design Project* **Denis Ring and Jorge Oliveira**	*Case Study on the Inaugural Design and Construction of a Refugee Shelter for Second Year Engineers* **Ruth Collins, Mark Dyer, Anthony Robinson and Kevin O'Kelly**
11:10 - 11:25	Coffee/Tea Break	
11:25 - 13:05	**Session 3 (Boole 1): Engineering Ethics & Sustainability in the Curriculum** **Chair: Dr Brian O'Gallachóir**	**Session 4 (Boole 2): Student Understanding** **Chair: Dr Kevin McCarthy**
11:25 - 11:45	*Towards An Integrated Approach To Engineering Ethics* **Eddie Conlon**	*Embedding 'Learning & Thinking styles' into Engineering Materials courses* **Plato Kapranos**
11:45 - 12:05	*Teaching ethics to civil engineers: Interdisciplinary reflections* **Raymond Flynn and John Barry**	*Research on student understanding as a guide for the development of instructional materials in introductory engineering courses* **Andrea Brose and Christian Kautz**
12:05 - 12:25	*A strategy for teaching quantitative sustainability assessment* **Stig Irving Olsen**	*Experiences of teaching, learning and assessment of student research skills on a Level 9 taught programme in engineering* **Aidan O'Dwyer**
12:25 - 12:45	*Integrating built environment studies through sustainable development education* **Alan Strong and Lesley Hemphill**	*Adapting to Engineering Education and Teaching Challenges* **Karl David Dearn, Athanasios Tsolakis, Thanos Megaritis and Doug Walton**
12:50 - 13:05	*A framework to develop lifelong learning and transferable skills in an engineering programme* **Gavin Duffy and Brian Bowe**	*Integral Approach to Enhance Engineering Education in an Off Shore University Campus* **Sarim Alzubaidy**

13:05 - 13:55	Lunch	
13:55 - 14:25	**Keynote 2** **Assoc. Prof. David Shallcross** (U. Melbourne, IChemE deputy President for Qualifications) *Sustainable Development In The Modern Engineering Curriculum* *(Boole 1)*	
14:25 - 15:15	*Professional Institutions' Forum*: Appropriate relationships between sustainability/ sustainable development and engineering education for the 21st Century* ***Senior representation from Engineers Australia, Engineers Ireland, Institution of Chemical Engineers, Institution of Mechanical Engineers** *(Boole 1)*	
15:15 - 15:30	Coffee/Tea Break	
15:30 - 17:30	**Session 5 (Boole 1):** **Future Perspectives** **Chair: Edward Conlon**	**Session 6 (Boole 2):** **Student Engagement & Learning Outcomes** **Chair: Dr Emanuel Popovici**
15:30 - 15:50	*The Role of the Professional Engineer in the 21st Century* **Aoife M. Foley and Paul G. Leahy**	*Pedagogical Impact of the MEETS on the Delivery of Engineering Courses* **William Cleghorn and Harpreet Dhariwa**
15:50 - 16:10	*Qualifying Energy's Value to Future Engineers and Scientists* **Ben Ebenhack and Daniel Martinez**	*First year fluids – encouraging student engagement when the class size is large* **Jonathan Cole and Stephen Spence**
16:10 - 16:30	*Implications of Secondary Level STEM Education on Engineering Student Recruitment* **Victoria Frazer, Juliana Early, Geoffrey Cunningham and Colette Murphy**	*Peer-Assisted Tutoring in Chemical Engineering* **Patricia Kieran, Dermot Malone and Geraldine O'Neill**
16:30 - 16:50	*Energy Engineering - is it a new engineering discipline or simply a pick and mix?* **Brian Ó'Gallachóir**	*The Impact of Senior Design Project Workload on Student Performance* **David Nobes, Curt Stout and Mark Ackerman.**
16:50 - 17:10	*Analysis of International Graduate Programmes Structures* **Dermot Brabazon, Sumsun Naher, Shadi Karazi and Gary Murphy**	*Project teaching in biomedical Engineering* **Daniela M. S. Campos and Ana C Queiroz**
17:10 - 17:30	*Some Finnish Visions of Engineering Education* **Timo Pieskä**	*The Formative Value of Peer Feedback in Project Based Assessment* **Raymond Lynch, Seamus Gordon and Niall Seery**


	Friday, 2nd July 2010	
08:50–09:00	**Day 2 Welcome & Introduction** *UCC Vice President for Teaching & Learning Prof. Grace Neville (Boole 1)*	
09:00–09:30	**Keynote 3 - Cheryl Desha** (Griffith University; Deputy Director, The Natural Edge Project, Australia) *Engineering Education & Sustainable Development: Rapid Curriculum Renewal (Boole 1)*	
09:30–11:10	**Session 7 (Boole 1):** **Teaching Sustainability** **Chair: Dr Patricia Kieran**	**Session 8 (Boole 2):** **Problem Based Learning (PBL)** **Chair: Dr Dermot Brabazon**
09:30–09:50	*Sustainability: words or do we really teach the engineers effectively?* **Jarka Glassey**	*Implementation of Project Based Learning in a Large Engineering Programme* **Gareth Bennett, Kevin Kelly, Ruth Collins, Frank Boland, Sara Pavia and Kevin O'Kelly**
09:50–10:10	*Teaching Sustainability through Catalysis* **Gregory Yablonsky, John Gleaves and Rebecca Fushimi**	*The use of CDIO methodology in creating an integrated curriculum for a new degree programme* **Hermon Paul, Charles McCartan and Geoff Cunningham**
10:10–10:30	*An engineering design course: developments over five years emphasising topics of sustainability* **Tom Joyce, Iain Evans and Bill Pallan**	*Educating Engineers as if they were Human: PBL in Civil Engineering at the University of Limerick* **Declan Phillips, Tom Cosgrove and Michael Quilligan**
10:30–10:50	*Teaching Strategies for Sustainability Management* **Rodney McDermott and Lynda Hegarty**	*Introduction of Problem Based Learning to Mechanical Engineering Curricula* **Jindrich Petruska**
10:50–11:10	*A New Graduate Course Teaching Chemical Engineering in use of Renewable Resources* **Hui Wang**	*Bridging the Gap - An Active/Interactive Approach to Introductory Aerospace Design Education* **Juliana Early, Adrian Murphy and Charles McCartan**
11:10–11:25	**Coffee/Tea Break**	
11:25–13:00	**Delegate Workshop – Cheryl Desha** *(UCC Council Room, North Wing, Quad)*	
13:00–13:50	**Lunch**	

13:50–14:20	**Keynote 4 – Prof. David Wood** (Chair World Chemical Engineering Council Executive, U. Melbourne, Tianjin U.) *Some global comparisons of Engineering Education – 21st Century style (Boole 1)*	
14:20–16:00	**Session 9 (Boole 1):** **Innovation & Information Technology** **Chair: Dr John Fitzpatrick**	**Session 10 (Boole 2):** **Developing Skills & Learning Outcomes** **Chair: Dr Plato Kapranos**
14:20–14:40	*Using video reports to promote active engagement in learning* **Peter Willmot and Tony Sutton**	*Outcomes Assessment in Chemical and Petroleum Engineering Programs* **Basim Abu-Jdayil, Hazim Al-Attar and Mohamed Mohamed Al-Marzouqi**
14:40–15:00	*Challenges in Providing Practical Labs Online to Distance Learning Students* **Marion McAfee and Stephen Reid**	*Critical thinking in the university curriculum* **Aoife Ahern, Martin McNamara, Tom O'Connor and Gerry MacRuairc**
15:00–15:20	*Accelerating Campus Entrepreneurship (ACE): A Sectional Analysis of Practices to Embed Entrepreneurship Education into Engineering at Irish Higer Education Institutions* **Cormac MacMahon, Maébh Coleman, Coleman Ledwith, Brian Cliffe and Róisín McGlone**	*Assessing the "Softer Skills" Learning Outcomes in Group Projects* **Hermon Paul and Charles McCartan**
15:20–15:40	*Capturing and Monitoring of Learning Process through a Business Process Management (BPM) Framework* **Ayodeji Adesina and Derek Molloy**	*Engineering Education in Service Systems* **Vittal Prabhu and Tao Yao**
15:40–16:00	*Engineering Community of Practice within the National Digital Learning Repository* **Dermot Brabazon**	*Engineering Education: Non-Traditional Specialisms, and The Smart Economy* **Sivakumar Ramachandran**
16:00–16:10	**Closing Session (Boole 1)** Including address from **Dr Plato Kapranos,** *The University of Sheffield, hosts of* ***ISEE2012***	

John Mullins

CEO, Bord Gáis

John Mullins was appointed Chief Executive of Bord Gáis in October 2007. John has worked in the international utility sector since graduating from UCC, starting his career with the ESB where he directed their largest international investment in Spain and then working as a senior consultant in Energy, Transport & Telecommunications with PWC in London. During his five years with NTR plc, John assisted Airtricity in its early development, was business development director during Greenstar's rapid growth in the waste sector and established Bioverda where he held the position of Chief Executive. John holds a Bachelors and a Masters Degree in Engineering from UCC and an MBA from the Smurfit School of Business in UCD.

Professor David Shallcross

Associate Professor David Shallcross is Head of the Department of Chemical and Biomolecular Engineering at the University of Melbourne. David has won several national and international awards recognizing his excellence and leadership in chemical engineering education including the 2006 Frank Morton Medal of the IChemE. He is the Founding Editor of the journal, Education for Chemical Engineers, and is a corresponding member of the European Federation of Chemical Engineering Working Party on Education. David was also recently appointed IChemE Vice-President.

Cheryl Desha

Cheryl is Deputy Director of The Natural Edge Project (TNEP), an 'Engineering for Sustainable Development and Climate Change' research group, based at Griffith University and the Australian National University, and lecturer in Griffith University's School of Engineering. In 2005 Cheryl was selected as the Engineers Australia Young Professional Engineer of the Year, and TNEP received the Australian Banksia Award for Environmental Leadership, Education and Training. TNEP have developed a range of projects focused on engineering education for sustainable development and rapid curriculum renewal, working across universities, professional bodies, government agencies, and companies.

Professor David Wood

David Wood is a chemical engineer and a Fellow of the IChemE, the IEAust and the RACI. He will be the President of the RACI later in 2010. He was a Vice President of the IChemE and Chair of the Australian Branch of the IChemE and in 2001 he chaired the 6th World Congress of Chemical Engineering in Melbourne, the first such congress to be held in the new style of world congresses. He was Head of Chemical Engineering at the University of Melbourne for 14 years and from 1997 to 2002 he was Dean of Engineering. Whilst he led an active research group in minerals processing at the University, since retiring he has concentrated on chemical engineering education including professional accreditation. He is an honorary professor at Tianjin University in North East China.

A Time for Universities to Develop and Market Engineering

John Mullins, Chief Executive Officer, Bord Gáis Éireann

This paper will address industry and society's requirement for third level educators to consider the education required by future engineers for a sustainable future. It will address bridging the gap between the current engineering curriculum and that required to provide innovative and prepared engineers, on which much of our sustainable future depends. The paper will also argue that there is a pressing need for re-positioning Engineering as an important career choice among school leavers. In order to do this, third level institutes must acknowledge and understand the priorities set by the broader economic context. Only then can they properly address re-modelling engineering education.

In order to promote engineering to its full potential, educators need to consider promoting engineering and recognising students with 'engineering potential' at a very young age. From an industry perspective, we must learn lessons from the past and recognise that second level is in fact too late to begin marketing engineering. For students showing strength and passion for maths and the sciences, the fulfilment, reward and possibilities associated with a career in engineering needs to be discussed and encouraged at a very young age. Collaboration between primary, post-primary and third level is vital to progress engineering education that will nurture those required to deliver for future generations.

Engineering Education & Sustainable Development: Rapid Curriculum Renewal

Cheryl Desha,
The Natural Edge Project (hosted by the Urban Research Program), Griffith University, Australia.

The issue of engineering education and how it can systemically embed sustainable development knowledge and skills is now a major consideration for engineering educators globally. In this plenary presentation Ms Desha will begin by highlighting the rapidly changing market and regulatory environment and the time lag dilemma facing higher education with regard to delivering professionals who can address societal needs. She will then briefly present a series of elements of curriculum renewal to support engineering educators who are grappling with how programs of study can be rapidly renewed to address such emerging 21st Century challenges. The presentation will conclude with a discussion of the need for a strategic approach by higher education institutions, to ensure that the latest research and opportunities are communicated, while being sufficiently pragmatic and realistic with regard to the scale of the challenges, and existing inertia within the higher education system.

Some Global Comparisons of Engineering Education "21st Century style!"

David Wood,
Professiorial Fellow, University of Melbourne

In 2009 at the 8th World Congress of Chemical Engineering I suggested that our universities had made an outstanding contribution to society in terms of research and new knowledge. In the same talk I argued that with respect to undergraduate chemical engineering education the universities and the professors of chemical engineering had let the profession and society down. The World allows us to continue delivering undergraduate chemical engineering programs that are unsustainable.

Chemical Engineering education has been formally recognised for over 100 years with people calling themselves chemical engineers in 1910 following the formation of the American Institute of Chemical Engineers. During this period university chemical engineering programs have drawn upon several paradigms which are well described by Hougen (1977) & Armstrong (2006).

In general the content of our undergraduate programs has been informed by modern developments both from research and from Industry. However, do we structure this content appropriately and what of the overall degree program structure?
In recent years we have seen strong suggestions for reform for both the curricular and the program structure e.g. Armstrong (MIT- Frontiers of Education project) (program), Bologna Accord (structure), Melbourne Model (program & structure). Each of these innovations have been proposed and in some cases implemented with significant opposition from traditionalists. An example of this is in the UK where there appears to be a great reluctance to even discuss the Bologna Accord let alone replace the traditional MEng program with the two stage Bologna program.

In China which is a Country which produces more chemical engineering graduates than the entire rest of the World only now are some universities adopting both structure and content of a standard equal to that in the UK and the USA. If the UK and the USA are leaders in content & structure what hope is there for the rest of us when Cussler (2005) refers to this content being 30 years out of date and Armstrong (2006) suggests 40 years out of date is valid?

The paper will provide commentary on the content & structure of the World's chemical engineering undergraduate programs and in particular will look at the Bologna program, the Melbourne Model and whether the Armstrong Frontiers approach can work within these structural models as well as in the traditional 4 year USA style program. In addition the impact of the Education revolution in China with respect to Chemical Engineering Education will be outlined.

The Decades of Undergrad. Progs.

(Hougen / Armstrong)

1905 - 1915 Industrial Chemistry	**1915 - 1925** Unit Operations	**1925 - 1935** Material & Energy Balances
1935 - 1945 Thermo & Control	**1945 - 1955** Kinetics Process Design	**1955 - 1965** Trans. Phen React. Eng. I.T.
1965 - 1975 Proc. Eng. Biochem.	**1975 - 1985** CAD Particles	**1985 - 1995** More CAD
1995 - 2005 Prod. Design Res.	**2005 - 2015** Biomolecular? Nano?	**2015 - 2025** ?

Sustainable Development in the Modern Engineering Curriculum

David C. Shallcross*
Melbourne School of Engineering, University of Melbourne, Melbourne, Victoria, 3010 Australia

Abstract: For a hundred years engineering education has focused on understanding the technical principles and basic sciences of the engineering disciplines. With the emergence of sustainable development as a topic that should be incorporated into the undergraduate curriculum there is some debate as to how best to integrate this topic into programs. Should this be done by a standalone subject, or should the issues be integrated throughout the curriculum? The role of learned engineering societies in promoting education in sustainable development is discussed with the Institution of Chemical Engineers used as an example. Finally the use of concept maps to assess student learning in sustainable development is discussed.

Keywords; sustainable development, concept maps, engineering education.

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1. INTRODUCTION:

There is a growing awareness worldwide of the importance of the concepts of sustainable development, that today and into the future we should aim to meet the needs of the present without compromising the ability of future generations to meet their own needs. Most people understand that uncontrolled and unsustainable development will lead to further species extinction, depletion of many of the world's already-scarce resources and the continued imbalance in national and societal wealth such as access to basic needs including adequate food, water, shelter and education. The changes that will need to be made to the ways of life of the world's populations in order to address the issues of sustainable development will require considerable social and technological advances.

Engineers of all disciplines will have the ability to make the most significant contributions to allowing the concepts of sustainable development to become a reality. Five of the fourteen grand challenges for the engineering profession in the 21st century as identified by the United States National Academy of Engineering (2010) relate to the development of technologies relevant to sustainable development and living – making solar energy economical, providing energy from fusion, developing carbon sequestration methods, managing the nitrogen cycle and providing access to clean water. If society will be turning to engineers to solve the problems of the coming decades then the concepts of sustainable developments must be part of the curriculum, and the engineering curriculum must be different. Writing nearly 40 years ago Schumacher (1973) observed that as the volume of education increases so too do pollution, exhaustion of resources and the dangers of ecological catastrophe. If still more education is to save us, it must be a different type of education.

Competencies around sustainable development can be delivered into engineering programs in many different ways – through the use of single standalone subjects on sustainable development that do not relate to other subjects in the program, through an integrated approach in which sustainable development concepts and settings are threaded throughout the entire program, or through a culture of sustainable development that pervades the entire fabric of the learning environment, a culture that involves everyone.

While the lack of a firm and agreed definition for sustainability may be considered an impediment by some, as Wals and Jicking (2002) note, the many faces of sustainability allow it to be approached from different angles:

- sustainability as contextual, its meaning is dependent on the situation in which it is used
- sustainability as vision, a goal to work towards,
- sustainability as dynamic and hence an evolving concept,
- sustainability as controversial and a source of conflict,
- sustainability as a catalyst for change,
- sustainability as ethical and moral,
- sustainability as a single step in the evolution of environmental education and discourse.

Thus sustainable development is an ideal context in which to undertake transdisciplinary activities including project work. It allows students to explore the roles of the engineer as an agent of change within a world of competing considerations. The context also permits the higher thinking skills of analysis, synthesis and evaluation to be engaged. De Graaff and Ravesteijn (2001) note that sustainable development should be a basic goal in the education of engineers and discuss the requirements for the training of a well-rounded engineer.

Wals and Jicking went on to note that successfully education in the sustainable development domain requires shifts in both teaching and learning styles:

- from teacher-centred to learner-centred activities;
- from individual learning to collaborative learning;
- from theory-dominated learning to learning centred on practice;
- from learning led by university-staff to learning from and with experts from outside the university;
- from consumptive learning to discovery learning and creative problem solving.

All these changes would take place in a system in which the student accepts more responsibility for their learning.

McKay and Raffo (2007) describe an interesting activity on sustainable design that was successfully used in the second year of an undergraduate engineering program at the University of Leeds.

2. THE ROLE OF PROFESSIONAL BODIES IN SUSTAINABLE DEVELOPMENT

There is a growing awareness worldwide of the importance of tIn May 2007 the Institution of Chemical Engineers released a document that looked at the future of the chemical engineering profession, "A Roadmap for the 21st Century Chemical Engineering" (IChemE, 2007). This document was compiled by voluntary members of the IChemE in consultation with its wider membership which at the time was 27,000 members in 100 countries. The core output from the review process was the development of a list of 20 position statements on issues of public concern. Three of these issues may be grouped together under the banner of sustainability and sustainable chemical technology:

- Sustainable Energy
- Reduce, Reuse, Recycle
- Sustainable Technology

The IChemE noted that the "… education of future generations of chemical engineers and realignment of the current generation with sustainability objectives is a vital component of the process of sustainable development." They observed that the incorporation of enhanced levels of sustainability into the core undergraduate chemical engineering curriculum as a result of global concerns today parallels the changes in process safety education within the United Kingdom following the major industrial accident at Flixborough in June 1974.

The IChemE is licensed by the Engineering Council of the United Kingdom (ECUK) to accredit undergraduate chemical engineering programs. As well as accrediting programs in the United Kingdom it accredits programs in Australia, China, Ireland, Malaysia, New Zealand, Singapore and Spain. Working through a framework set by the ECUK the IChemE has developed a set of guidelines for accreditation of chemical engineering programs at the highest level.

The links between the observations of the IChemE's Roadmap document and its accreditation responsibilities are obvious. Important recommendations of the Roadmap were for the IChemE to "… continue its programme to integrate sustainable development into the core curriculum and ensure the accreditation process reflects its importance…" and that it will "… ensure that sustainable development is a component of CPD; and will work with other stakeholders to ensure such education is not resource constrained".

The IChemE, a member-driven body therefore recognizes the important role it has in ensuring that any chemical engineering program which it accredits addresses the issue of sustainable development somewhere in its program. However like its requirement for the covering of process safety there are no set specifications on how this topic is to be addressed. All accredited programs must address sustainable development.

3. CONCEPT MAPS AS A TOOL FOR UNDERSTANDING STUDENT LEARNING

There is a growing awareness worldwide of the importance of Concept maps were first developed in the 1970's to graphical represent knowledge and understanding of particular domains or topics. In a typical map the domain is written in the centre and then other concepts are linked to the domain via connecting lines and words. These first generation concepts are in turn connected to second generation concepts by more connecting lines. Interconnecting lines between concepts of the same and/or different generations from the central domain allow the maps' authors to demonstrate the links that they see between different concepts. In the last decade a number of workers have turned to concept maps to assess the understanding of student cohorts of a range of topics. As an example, Iuli and Helldén (2004) constructed concept maps based upon student interviews to assess the students' conceptions of various aspects of science.

The preparation of a concept map on any topic requires the student to analyze, synthesize and evaluate information in a high level manner. This is not a simple task. The manner in which the concept map is constructed reveals much about the thinking, maturity and knowledge of the student in the particular domain.

Lourdel et al. (2007) and Segalas et al. (2008; 2010) have both used concept maps to study student understanding of sustainable development concepts. Lourdel et al. (2007) proposed that each concept in a map may be classified as belonging to one of six categories (Table 1):

1 environmental
2 social, cultural
3 multidimensional approaches
4 economic, scientific, technological
5 procedural and political approaches
6 actors and stakeholders

Later Segalas et al. (2008) expanded the number of categories to ten by splitting several of Lourdel's categories. They added 'Resource scarcity' and 'Education' and replaced 'Multidimensional analysis' by 'Future generations' which essentially accounts for intergeneration equity considerations and 'Unbalances' which accounts for intragenerational equity aspects.

CATEGORIES		
Lourdel et al. (2007)	**Segalas et al. (2008)**	**This Study**
1. Environmental	1. Environmental	1. Environmental
	2. Resources scarcity	2. Resources scarcity
2. Social cultural	3. Social impact	3. Social impacts and values
	4. Values	
3. Multidimensional approaches	5. Future generations (temporal)	4. Intragenerational and
	6. Unbalances (spatial)	intergenerational equity
4. Economic, scientific, technological	7. Technology	5. Technology
	8. Economy	6. Economic
5. Procedural and political approaches	9. Education	7. Education
6. Actors and stakeholders	10. Actors and stakeholders	8. Actors and stakeholders

Table 1 : Taxonomy of sustainable development categories used in this and earlier studies

The classification of concepts requires considerable subjective judgment on the part of the person performing the analysis. Depending on the context including the linking words and the surrounding concepts, single word concepts such as 'justice', 'water' and 'jobs' might well be classified into one of several categories. The more categories there are within a taxonomy the greater the likelihood for classification errors.

In the present study an eight-category taxonomy is proposed that maps onto the earlier work of Loudel et al. (2007) and Segalas et al. (2008; 2010) a shown in Table 1. The eight categories are together with representative concepts are:

1. **Environmental**
   global warming, drought, plants, animals, energy, waste, carbon dioxide, pollution, climate change, deforestation
2. **Resources scarcity**
   non-renewable energy sources, non-renewable material, coal
3. **Social impacts and values**
   ethics, safety, laws, needs, wants, shelter, food, recycling, jobs and actions such as less power usage, reduce deforestation
4. **Intragenerational and intergenerational equit**y
   future generation, equity, poverty, the future, living standards, quality of life, justice
5. **Technological**
   recycling, research, efficient design, machinery, fuel cells, wind power, lie cycle assessment, wind turbine, desalination
6. **Economic**
   profit, carbon tax, carbon trading, energy cost, material cost, economic growth
7. **Education**
   public awareness programs, training
8. **Actors and Stakeholders**
   community, consumers, countries, engineers, government, politicians

In the first semester of 2009, 750 students enrolled in the first year engineering subject Engineering Systems Design 1 at the University of Melbourne were asked to prepare concept maps based around the domain 'Sustainable Development'. They had previously received instructions in the preparation of concept maps and had several opportunities to practice on other topics. They were each given an A4-sized sheet of paper with the domain written in its centre and asked to handwrite their concept maps in 20 minutes. Of the maps submitted 732 were found to be valid and were analyzed – 589 were completed by males and 143 by females. Approximately 30 % of the student cohort did not have English as their first language.

To illustrate the range of concept maps developed the concepts maps prepared by two students selected at random are presented in Figures 1 and 2. The map of Student 1 contains just 16 concepts linked by 23 links. This map features 5 concepts that refer to 'Resources scarcity', another 5 that refer to 'Technological' and 4 that relate to 'Environmental'. In contrast the map of Student 2 contains 80 concepts with over 33 relating to 'Social impacts and values' and 28 relating to 'Technological'.

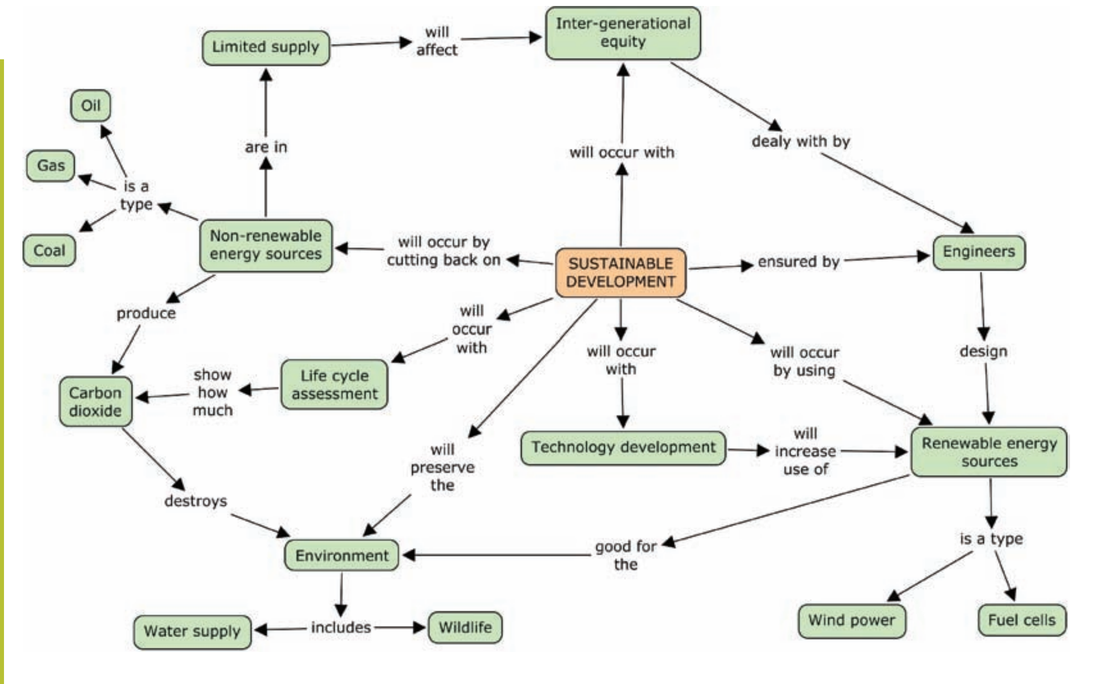
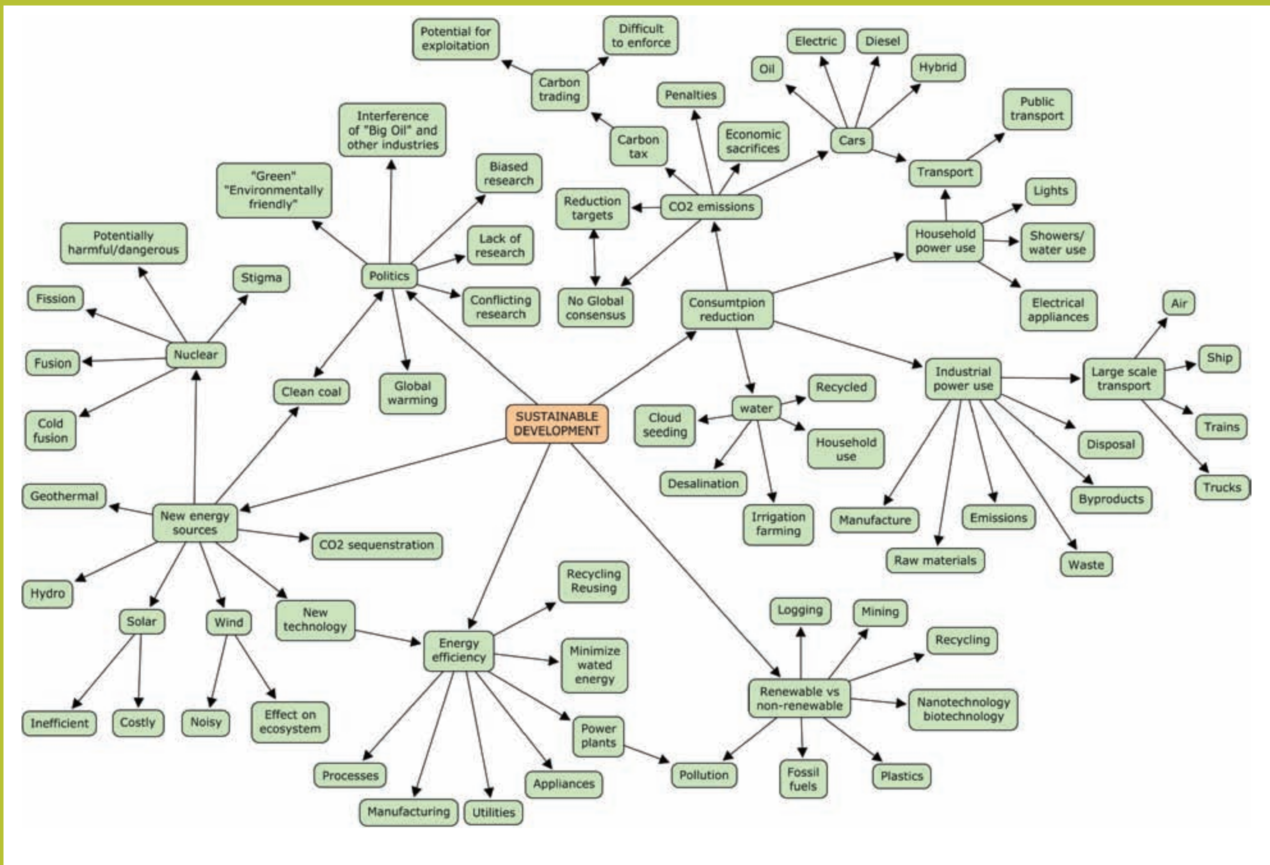


Figure 1 : Concept map of Student 1 featuring 16 concepts and 23 links.

Figure 2 : Concept map of Student 2 featuring 80 concepts and 85 links.



While the individual maps prepared by students vary significantly it is possible to gain a sense of the understanding of the class as a whole to the domain “Sustainable development”. When all 723 valid concept maps were analyzed with each concept shown on the maps assigned to one of the eight categories it was found that most first year engineering students at the University of Melbourne focus on the technological aspects of the issue. On average each concept map contained 9.8 concepts that were categorized as ‘technological’, 6.4 concepts relating to ‘society impacts and values’, 6.2 concepts relating to ‘environmental’ and less than 2.5 relating to each of the remaining five categories (Figure 3). On average each concept map contained 29.7 concepts and 39.0 links. There was little difference in the maps prepared by males and females. These results suggest that at the University of Melbourne greater emphasis could be placed on the roles and responsibilities of engineers and others in society as well as the issues around intergenerational and intragenerational equity.

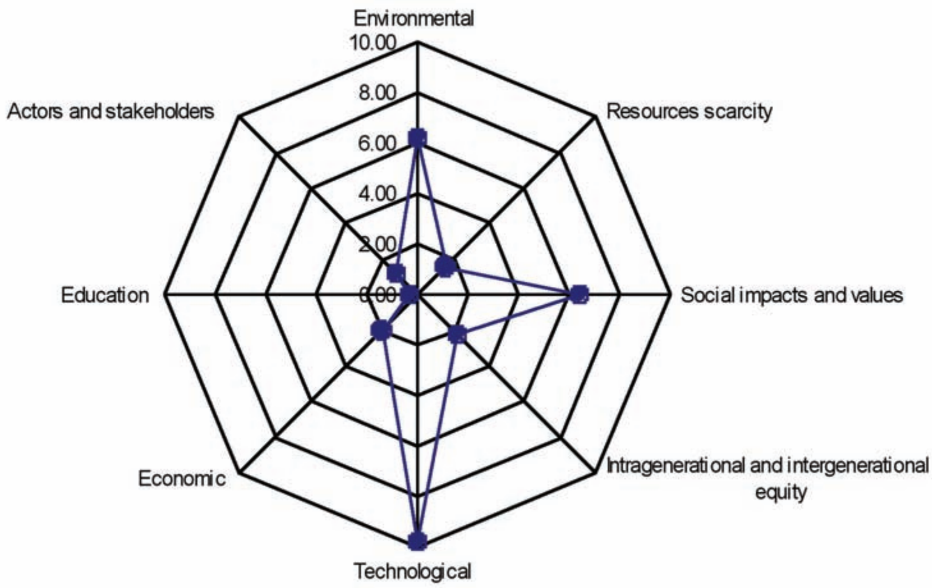


Figure 3 : Average number of concepts in each of the 732 concept maps analyzed.

By having students complete a concept map at the beginning and end of a unit of study or an entire degree program, it is possible to observe the change in students' understanding of the topic. It would be expected that the concept map would become more complex, with more concepts, representing all the major categories with more cross-links between different branches of the map. It is the intention of the author to conduct a further survey of the students originally surveyed in early 2009 when they are completing their courses in 2012 and 2013.

4. CONCLUDING REMARKS

Of all the professions it is probably the engineers who will play the major roles in addressing the broad issues facing the world today of climate change and the necessity for sustainable development. This requires that engineering students are given an education which allows them to meet the challenges of the coming decades. They must have an awareness of the issues of sustainable development and they must be empowered with the tools of team work, problem solving and effective teamwork. They must be able to work in interdisciplinary teams on challenges greater than imagined before. Engineering educators must meet this challenge by being flexible in both the course content and the manner of its delivery.

5. REFERENCES

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Professional Engineering Forum

Theme:
Appropriate relationships between sustainability/sustainable development and engineering education for the 21st Century

Time: 14.25-15.15, Thursday 1st July 2010
Venue: Boole 1, UCC
Facilitator: Assoc. Professor David Shallcross, Qualifications Vice President IChemE.

ISEE2010 will incorporate a Professional Institutions Forum where delegates will be afforded the opportunity to hear from a number of Professional Institutions on their conception of the future appropriate relationship between sustainable development/sustainability and professional engineering education. The forum will allow for an interactive discussion and reflection on the issues involved.

The forum will be chaired by Associate Professor David Shallcross, Qualifications Vice President of IChemE and editor of the IChemE/EFCE transactions journal "Education for Chemical Engineers". Professor Shallcross is Head of the Department of Chemical & Biomolecular Engineering at the University of Melbourne and is a widely published authority on engineering education. Professor Shallcross will deliver a keynote presentation just preceding the forum where he will reflect on the potential relationships between sustainability and engineering education, drawing upon his own research and publications in this area.

Participating Institution:	Representative:
Engineers Australia	**Prof. Alan Bradley** (Associate Director Accreditation)
Engineers Ireland	**John Power** (Director General)
IChemE	**Dr Colin Pritchard,** University of Edinburgh (IChemE Sustainability Subject Group Executive)
IMechE	**Prof. Joseph Tatler,** Glyndwr University (University of Wales)

Each of the panel members will make a brief (5-7 minute) presentation outlining their own respective institutions' conception of the appropriate relationship between sustainability and their professional programmes and practice in the 21st Century. After that, there will be an open discussion session involving delegates and the panel, which will be moderated by Professor Shallcross.

Professional Institutions
Forum Panel Members

John Power BE CEng FIEI
Chartered Engineer

John Power is Director General of Engineers Ireland. Prior to joining Engineers Ireland in September 2007 he was Head of Corporate Affairs at ESB. John has held several key positions during his time with ESB; Managing Director of ESBI Consultants, Executive Director of ESB International Services, as well as holding senior roles in Human Resources and Corporate Change. Before joining ESB, he was a Technical Advisor with General Electric in the USA and in South America. John is a graduate of UCD, holding a Masters in Industrial Engineering and an MBA. A native of Tralee, Co Kerry, he was also Secretary of the Irish Committee of the World Energy Council.

Emeritus Professor Alan B Bradley
FIEAust CPEng

Professor Bradley was appointed to the position of Engineers Australia – Associate Director Accreditation in February of 2002 following a 30-year career at RMIT University holding the positions of Associate Dean and Head of Department of Communication and Electronic Engineering. His academic career included leadership of a Signal Processing Research Group within the Centre for Advanced Technology in Telecommunications.

On behalf of the Engineers Australia Accreditation Board, Professor Bradley manages the systems and processes of accreditation for engineering education programs implemented by Australian educational institutions both in Australia and internationally. Professor Bradley is also influential in the activities of the Washington Accord and other education accords under the International Engineering Alliance. This work involves mutual recognition processes between signatory nations, the development and maintenance of exemplar graduate outcome statements, periodic monitory of signatory accreditation systems and the mentoring of new jurisdictions seeking admission to the accords.

Dr. Colin Pritchard EurIng
CEng CEnv FIChemE

Colin Pritchard is a chartered chemical engineer and environmentalist, and Senior Research Fellow in the Institute for Energy Systems at Edinburgh University. He has over 40 years' experience in energy recovery, low-energy separations and industrial energy systems. He is currently working on biomass conversion technologies in an international consortium funded by DfID; and on Engineering Education in Africa with the UK National Commission for UNESCO.

He has served on the IChemE International Committee, as Chair of the Scottish Branch, and as a Trustee of “Engineers Against Poverty”; and is a member of its Sustainability Committee. He runs a sports charity in Uganda.

Delegate Workshop

Theme:
Accreditation & Sustainable Engineering

Time: 11.25-13.00, Friday 2nd July 2010
Venue: Council Room, North Wing, Quad, UCC
Facilitator: Cheryl Desha, Education Director, The Natural Edge Project

Background:
The issue of sustainability and its appropriate role in engineering education has been the focus of growing awareness among the engineering education community globally, particularly over the last decade. However, while there have been calls for embedding sustainability content throughout engineering curricula since the 1990s, there has been little by way of strategic and systematic integration.
Meanwhile professional engineering institutions (PEIs) have shown an increasing awareness of this area and have been behind several recent and ongoing initiatives which have addressed the role of the engineer in helping create a sustainable society. Accreditation plays a major role as a key driver and monitor of curriculum evolution and renewal efforts. Hence, the issue of appropriately embedding sustainable development within engineering curriculum will be inevitably considered by PEIs over future accreditation reviews and guideline iterations.

Workshop:
The 1.5 hour highly interactive workshop will provide an opportunity for professional engineering institution accreditors and educators to discuss emerging accreditation themes internationally, particularly in relation to EESD. A background paper[1] has been produced for workshop delegates (paper follows), which overviews current international practices with respect to accreditation requirements in the context of evolving policies and initiatives by various professional institutions.

With this context in mind, delegates will have an opportunity to share their findings and experiences. Delegates will be asked to reflect on the following questions:

1. *What are the Sustainability / Sustainable Development themes that might be incorporated into engineering curricula for the second decade of the 21st Century and beyond?*

2. *How might these themes manifest themselves in practical terms throughout accreditation themes through guidelines of Professional Engineering Institutions?*

Delegates will receive a copy of the compiled results and key findings will be published in a relevant forum, to contribute to a broader conversation globally.

1. Byrne, E., Desha, C., Fitzpatrick, J. & Hargroves, K. (2010). ‚Engineering Education for Sustainable Development: A Review of International Progress‘, workshop paper for the 3rd International Symposium for Engineering Education, 30 June - July 2010.

Symposium - Workshop Interaction:

As part of the Cheryl Desha's keynote address (9.00-9.30am, Boole 1, Friday 2 July 2010), delegates will be asked to peruse a list of emerging themes:

1) ranking the themes that have been identified with regard to how well each is currently addressed;
2) nominating other sustainability competencies (or 'generic attributes') that should be incorporated; and
3) listing any crucial recommendations that accreditation bodies should consider when reviewing their core competency statements for sustainability content.

These results will be compiled to feed into the workshop.

Examples - Statements & Themes:

For example, two core competencies related to sustainability and sustainable development in the Engineers Australia accreditation documentation are:

g) understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development;
h) understanding of the principles of sustainable design and development;

From these, the following themes may be distilled:

– Social responsibilities
– Cultural responsibilities
– Global responsibilities
– Environmental responsibilities
– The need for sustainable development
– Principles of sustainable design
– Principles of sustainable development

Background – Facilitator:

Cheryl Desha, Education Director of The Natural Edge Project (TNEP), is an Environmental Engineer and co-author to a number of publications including 'Cents & Sustainability: Securing Our Common Future by Decoupling Economic Growth from Environmental Pressure' (2010), 'Factor 5: Transforming the Global Economy through 80% Improvements in Resource Productivity (2010)', 'Whole System Design: An Integrated Approach to Sustainable Engineering (2009)' and 'The Natural Advantage of Nations: Business Opportunities, Innovation and Governance in the 21st Century' (2005). Cheryl will deliver a keynote speech at ISEE 2010 and launch TNEP's publication 'Engineering Education & Sustainable Development: A Guide for Rapid Curriculum Renewal in Higher Education' at the Symposium.

The Natural Edge Project (TNEP) is a not-for profit partnership for research and education on sustainable development. Formerly hosted by Engineers Australia (2002-2006), the project is now hosted by Griffith University and the Australian National University (www.naturaledgeproject.net). TNEP's mission is to contribute to and succinctly communicate leading research, case studies, tools and strategies for achieving sustainable prosperity across government, business and civil society.

Delegate Workshop Context Paper is available at

http://www.ucc.ie/isee2010/workshop.html

Delegate Workshop Context Paper

Engineering Education for Sustainable Development: A Review of International Progress

Edmond Byrne[1], Cheryl Desha[2], John Fitzpatrick[1] and Karlson Hargroves[3]

1. Department of Process and Chemical Engineering, University College Cork, Ireland.
2. The Natural Edge Project (Urban Research Program), Griffith University, Australia.
3. The Natural Edge Project (Urban Research Program), Griffith University, Australia. Curtin University, Australia.

International
Advisory Panel (IAP)

ISEE2010 would like to sincerely thank our distinguished International Advisory Panel members for agreeing to undertake and for making the time to review the papers submitted to the Symposium. Their contributions in reviewing the papers have been invaluable.

Alison Ahearn	Imperial College London
Brad Allenby	Arizona State University
Adisa Azapagic	The University of Manchester
Brian Bowe	Dublin Institute of Technology
Conor Brennan	Dublin City University
Louis L. Bucciarelli	Massachusetts Institute of Technology
Anthony Bull	Imperial College London
Richard Cadbury	London South Bank University
Mike Clifford	The University of Nottingham
Jonathan Cole	Queen's University Belfast
Edward Conlon	Dublin Institute of Technology
Siobhan Cox	Queen's University Belfast
Michael Creed	University College Cork
Cheryl Desha	The Natural Edge Project, Griffith University
Toby Cumberbatch	The Cooper Union, New York
George Drahun	Aston University
Paul Dillon	Institute of Technology Tallaght, Dublin
Pavel Dobis	Brno University of Technology
David Dowling	University of Southern Queensland
Eric Favre	ENSIC - Nancy Université
Richard Felder	North Carolina State University
Didac Ferrer-Balas	Universitat Polytècnica de Catalunya
Juan García Serna	Universidad de Valladolid
William Gaughran	University of Limerick
Vincent Gomes	The University of Sydney
Roger Hadgraft	The University of Melbourne
Carolyn S. Hayles	Queen's University Belfast
Mark Henderson	Arizona State University
Neil Hewitt	University of Ulster
Plato Kapranos	The University of Sheffield
Declan Kennedy	University College Cork
Bob Lawlor	National University of Ireland, Maynooth
Huw Lewis	University of Limerick
Lisa Looney	Dublin City University
Kevin McCarthy	University College Cork
Dieter Meissner	Tallinn University of Technology

Karel Mulder	TU Delft
Sumsun Naher	Dublin City University
Brian O'Gallachóir	University College Cork
Abdul Olabi	Dublin City University
John O'Shea	Cork Institute of Technology
Catherine O'Sullivan	Imperial College London
Robert W. Peters	University of Alabama at Birmingham
Declan Phillips	University of Limerick
Timo Pieskä	Oulu University AS
Emmanuel Popovici	University College Cork
Martin Pitt	The University of Sheffield
Colin Pritchard	The University of Edinburgh
Nathan Quinlan	NUI Galway
Shahin Rahimifard	Loughborough University
Jordi Segalàs	Universitat Polytècnica de Catalunya
David Shallcross	The University of Melbourne
Tim Short	University of Liverpool
Magdalena Svanström	Chalmers University of Technology
David Timoney	University College Dublin
Bland Tomkinson	The University of Manchester
Panos Tsakiropoulos	The University of Sheffield
Harro von Blottnitz	University of Cape Town
Paul W. Jowitt	Herriot Watt University (ICE President, 2009-2010)
Malcolm Wilkinson	IChemE (Chair; Sustainable Development SG)
Richard Wakeman	Loughborough University
Gregory Yablonsky	St. Louis University & Washington University in St. Louis

Best Paper Awards

All papers at ISEE2010 have been subject to a peer review process by at least two members of the ISEE2010 International Advisory Panel. A small panel comprising of a number of Keynote and PEI Forum speakers have selected the best overall paper from a selection of the best papers as designated by the IAP. They have also selected in addition, three runners up papers.

All paper award winners will be presented with beautiful individually produced Elm Bowls by local woodturner Tony Farrell. The presentations will be made as part of the ISEE2010 opening welcome address by Professor Patrick Fitzpatrick, Head, College of Science, Engineering & Food Science at **8.50am on Thursday 1st July in Boole 1.**

Profile of Tony Farrell - Woodturner

Supplier of Elm Bowls as presented for Best Paper Awards

I have been woodturning at my workshop in Ballinora, Co. Cork on a part time basis since 1998. Recently retired, I am now working full time at woodturning. I make bowls and lamps from Irish grown woods, which I harvest and season myself. I am currently working on making hollow forms as an addition to my range of work.

All my timber is harvested from either dead/storm felled trees or trees which are being felled for development or other reasons. For woodturning I try and keep the pieces of log as large as possible as there is always some loss of length due to the seasoning process. I typically use oak, ash, elm, sycamore, beech, apple, cherry, sweet chestnut, yew and others.

Seasoning takes at least six months and can take up to two years depending on the type of wood and condition of the tree before it is harvested. Typically a log will be air dried in the round for a few months before being cut into blanks and rough turned. The rough turned blanks are then dried in a container, which has a dehumidifier installed to dry the air. This process is slow but means less loss of work due to cracking. When the rough-turned blanks are dry they are finish turned and polished in the workshop. I finish my lamps with a final polish of wax. They can be polished with furniture polish or wax.

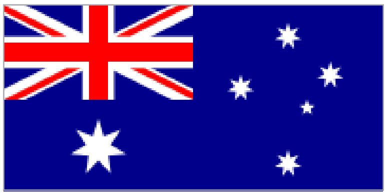
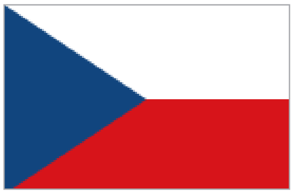
I finish my bowls with an oil which is based on Tung nut oil. This gives a finish which is durable and hard wearing. Prolonged use of salad oils and vinegar will remove this finish in time. Bowls can be refinished if needed. An alternative treatment is to rub such bowls with a good salad oil such as olive oil. Never put one in the dishwasher. The high water temperature will ruin your bowl.

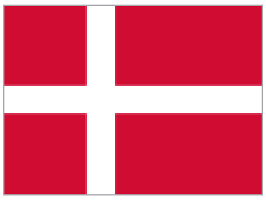
For further information please visit

www.tonyfarrell.ie

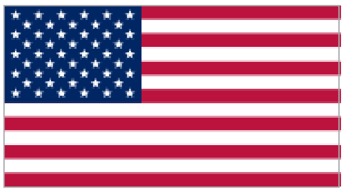
List of ISEE2010 Papers

The following is a full list of papers presented at ISEE2010 in both oral and poster formats. The list is in alphabetical order, based on the lead author. ISEE2010 is delighted to present almost 80 papers from all six continents across the globe. There's a line up of contributions that any World Cup organizer would be proud of, from South Africa to Scotland and from Australia to Canada via the United Arab Emirates, and many more in between. Welcome all!
Full papers will be available online at:
http://www.ucc.ie/isee2010/papers.html
ISSN: 2009-3225

Abu-Jdayil, Basim, Al-Attar, Hazim and Al-Marzouqi, Mohamed
United Arab Emirates University, UAE
Outcomes Assessment in Chemical and Petroleum Engineering Programs
10: Developing Skills & Learning Outcomes 14:20 - 14:40, Fri 2nd, Boole 2

Adams, Karen, Ripper, Margie, Zander, Anthony and Mullins, Gerry
The University of Adelaide, Australia
The Valuing of Creativity in the Workplace Roles of Engineering Research Graduates
1: Industry Perspectives 09:30 - 09:50, Thu 1st, Boole 1

Adesina, Ayodeji and Molloy, Derek
Dublin City University, Republic of Ireland
Capturing and Monitoring of Learning Process through a Business Process Management (BPM) Framework
9: Innovation & Information Technology 15:20 - 15:40, Fri 2nd, Boole 1

Ahern, Aoife, McNamara, Martin, O'Connor, Tom and MacRuairc, Gerry
University College Dublin, Republic of Ireland
Critical Thinking in the University Curriculum
10: Developing Skills & Learning Outcomes 14:40 - 15:00, Fri 2nd, Boole 2

Al-Attar, Hazim, Abu-Jdayil, Basim and Al-Marzouqi, Mohamed
United Arab Emirates University, UAE
Assessment of Educational Objectives in Chemical and Petroleum Engineering Programs
Paper presentation in poster format

Alpay, Esat, Bull, Anthony and Ahearn, Alison
Imperial College London, England
Cross-Departmental Initiatives for a Global Dimension in Engineering Education
2: Global Perspectives 09:50 - 10:10, Thu 1st, Boole 2

Al-Zubaidy, Sarim
Heriot-Watt University Dubai Campus, United Arab Emirates
Integral Approach to Enhance Engineering Education in an Off Shore University Campus
4: Student Understanding 12:45 - 13:05, Thu 1st, Boole 2

Baha, Bahawodin and Katz, Tim
University of Brighton, England
The Effect of University Partnerships on Engineering Education in Afghanistan
Paper presentation in poster format

Barrow, George, Heinemann, Robert and Hinduja, Srichand
The University of Manchester, England
Manufacturing Engineering Education Across Europe
2: Global Perspectives 10:30 - 10:50, Thu 1st, Boole 2

Bennett, Gareth, Kelly, Kevin, Collins, Ruth, Boland, Frank, McGoldrick, Ciaran, Pavia, Sara and O'Kelly, Kevin
Trinity College Dublin, Republic of Ireland
Implementation of Project Based Learning in a Large Engineering Programme
8: Problem Based Learning 09:30 - 09:50, Fri 2nd, Boole 2

Blaskovsky, Cintia, Portilho Camargos Gomes, Lucas and Alves Rodrigues Blaskovsky, Isabel Maria Cristina
Universidade do Estado do Pará, Universidade de Itaúna & Universidade Federal do Pará, Brazil
Comparative Studies on the Teaching of "Sustainability" in the Program Courses of Industrial Engineering from Five Public Universities in Brazil
Paper presentation in poster format

Brabazon, Dermot
National Digital Learning Repository, Republic of Ireland
Engineering Community of Practice within the National Digital Learning Repository
9: Innovation & Information Technology 15:40 - 16:00, Fri 2nd, Boole 1

Brabazon, Dermot, Naher, Sumsun, Karazi, Shadi and Murphy, Gary
Dublin City University, Republic of Ireland
Analysis of International Graduate Programme Structures for Engineering Education
5: Future Perspectives 16:50 - 17:10, Thu 1st, Boole 1

Brose, Andrea and Kautz, Christian
Hamburg University of Technology, Germany
Research on student understanding as a guide for the development of instructional materials in introductory engineering courses
4: Student Understanding 11:45 - 12:05, Thu 1st, Boole 2

Campos , Daniela M. S. and Queiroz, Ana C.
ESEIG - Instituto Politécnico do Porto, Portugal
Project Teaching in Biomedical Engineering
6: Student Engagement & Learning Outcomes 16:50 - 17:10, Thu 1st, Boole 2

Cleghorn, William and Dhariwal, Harpreet
University of Toronto, Canada
Pedagogical Impact of the Multimedia Enhanced Electronic Teaching System (MEETS) on the Delivery of Engineering Courses
6: Student Engagement & Learning Outcomes 15:15 - 15:35, Thu 1st, Boole 2

Cole, Jonathan and Spence, Stephen
Queen's University Belfast, Northern Ireland
First Year Fluids – Encouraging Student Engagement When the Class Size is Large
6: Student Engagement & Learning Outcomes 15:35 - 15:55, Thu 1st, Boole 2

Cole, Jonathan, Price, Mark and Davies, Gary
Queen's University Belfast, Northern Ireland
Developing Maths and Computing Skills in the Context of an Integrated Curriculum
Paper presentation in poster format

Collins, Ruth, Dyer, Mark, Robinson, Anthony and O'Kelly, Kevin
Trinity College Dublin, Republic of Ireland
Case Study on the Inaugural Design and Construction of a Refugee Shelter for Second Year Engineers
2: Global Perspectives 10:50 - 11:10, Thu 1st, Boole 2

Conlon, Eddie
Dublin Institute of Technology, Republic of Ireland
Towards an Integrated Approach to Engineering Ethics
3: Engineering Ethics & Sustainability in the Curriculum 11:25 - 11:45, Thu 1st, Boole 1

Cosgrove, Tom, Phillips, Declan and Quilligan, Michael
University of Limerick, Republic of Ireland
Educating Engineers as if they were Human: PBL in Civil Engineering at the University of Limerick
8: Problem Based Learning 10:10 - 10:30, Fri 2nd, Boole 2

Dearn, Karl David, Tsolakis, Athanasios, Megaritis, Thanos and Walton, Doug
The University of Birmingham & Brunel University, England
Adapting to Engineering Educational and Teaching Challenges
4: Student Understanding 12:25 - 12:45, Thu 1st, Boole 2

Dobis, Pavel, Bruestlova, Jitka and Bartlova, Milada
Brno University of Technology, Czech Republic
Curie Temperature in Ferromagnetic Materials and Visualized Magnetic Domains
Paper presentation in poster format

Duffy, Gavin and Bowe, Brian
Dublin Institute of Technology, Republic of Ireland
A Framework to Develop Lifelong Learning and Transferable Skills in an Engineering Programme
3: Engineering Ethics & Sustainability in the Curriculum 12:45 - 13:05, Thu 1st, Boole 1

Dunphy, Louise and O'Dwyer, John
Waterford Institute of Technology, Republic of Ireland
Innovative Technologies: The Educational Challenges
Paper presentation in poster format

Dwyer, Brian and Byrne, Edmond
Energetics Pty. Ltd., Australia and University College Cork, Republic of Ireland
Practical Skills and Techniques for the Transition to a Sustainable Future, a Case Study for Engineering Education
1: Industry Perspectives 10:10 - 10:30, Thu 1st, Boole 1

Early, Juliana, Murphy, Adrian and McCartan, Charles
Queen's University Belfast, Northern Ireland
Bridging the Gap - An Active/Interactive Approach to Introductory Aerospace Design Education
8: Problem Based Learning 10:50 - 11:10, Fri 2nd, Boole 2

Ebenhack, Ben and Martinez, Daniel
University of Rochester & University of Southern Maine, United States
Qualifying Energy's Value to Future Engineers and Scientists
5: Future Perspectives 15:35 - 15:55, Thu 1st, Boole 1

Faleye, Sunday, and Mogari, David L.
University of South Africa, South Africa
Method of Teaching Fluid Mechanics in some South African Universities and Its Implications for Learning
Paper presentation in poster format

Fitzpatrick, Colin
University of Limerick, Republic of Ireland
Integrating Environmental and Social Considerations in the Curriculum of Undergraduate Electronic and Computer Engineering Students
Paper presentation in poster format

Flynn, Raymond and Barry, John
Queen's University Belfast, Northern Ireland
Teaching Ethics to Engineers –Reflections on an Interdisciplinary Approach
3: Engineering Ethics & Sustainability in the Curriculum 11:45 - 12:05, Thu 1st, Boole 1

Foley, Aoife M. and Leahy, Paul G.
University College Cork, Republic of Ireland
The Role of the Professional Engineer in the 21st Century
5: Future Perspectives 15:15 - 15:35, Thu 1st, Boole 1

Frazer, Victoria, Early Juliana, Cunningham, Geoffrey and Murphy, Colette
Queen's University Belfast, Northern Ireland
Implications of Secondary Level STEM Education on Engineering Students in Northern Ireland
5: Future Perspectives 15:55 - 16:15, Thu 1st, Boole 1

Gibson, Peter and Childs, Peter
University of Wollongong, Australia
Graduating professional engineers and management skills – are they adequate for the workplace?
1: Industry Perspectives 10:30 - 10:50, Thu 1st, Boole 1

Glassey, Jarka
Newcastle University, England
Sustainability: Words or do we really Teach the Engineers Effectively?
7: Teaching Sustainability 09:30 - 09:50, Fri 2nd, Boole 1

Grepl, Robert
Brno University of Technology, Czech Republic
Problem Based Learning in Mechatronics
Paper presentation in poster format

Hermon, Paul and McCartan, Charles
Queen's University Belfast, Northern Ireland
Assessing the "Softer Skills" Learning Outcomes in Group Projects
10: Developing Skills & Learning Outcomes 15:00 - 15:20, Fri 2nd, Boole 2

Hermon, Paul, McCartan, Charles and Cunningham, Geoff
Queen's University Belfast, Northern Ireland
The Use of CDIO Methodology in Creating an Integrated Curriculum for a New Degree Programme
8: Problem Based Learning 09:50 - 10:10, Fri 2nd, Boole 2

Joyce, Thomas
Newcastle University, England
Use of Web-based Software and Joint Models to Teach Anatomy to Engineering Students
Paper presentation in poster format

Joyce, Thomas and Dunne, Nicholas
Newcastle University, England & Queen's University Belfast, Northern Ireland
A Comparison of Interactive Teaching Methods used in Bioengineering/Biomaterials Modules at Two Russell Group Universities
Paper presentation in poster format

Joyce, Tom, Evans, Iain and Pallan, William
Newcastle University, England
An Engineering Design Course: Developments over Five Years Emphasising Topics of Sustainability
7: Teaching Sustainability 10:10 - 10:30, Fri 2nd, Boole 1

Kapranos, Plato
The University of Sheffield, England
Embedding 'Learning & Thinking Styles' into Engineering Materials Courses
4: Student Understanding 11:25 - 11:45, Thu 1st, Boole 2

Kapranos, Plato
The University of Sheffield, England
Cradle to ? Introducing 'Environmental Issues' into the teaching of Engineering Materials
Paper presentation in poster format

Kapranos, Plato
The University of Sheffield, England
Entrepreneurship & Innovation in Materials Engineering
Paper presentation in poster format

Kieran, Patricia, Malone, Dermot and O'Neill, Geraldine
University College Dublin, Republic of Ireland
Peer-Assisted Tutoring in Chemical Engineering – Development of a Tutor-Oriented Module
6: Student Engagement & Learning Outcomes 15:55 - 16:15, Thu 1st, Boole 2

Lambert, Chris and Rennie, Allan
Lancaster University, England
Placing Postgraduate Research Students at the Heart of Knowledge Exchange: Benefits for Academia and Industry
Paper presentation in poster format

Ledwith, Ann, Risquez, Angelica and O'Dwyer, Michele
University of Limerick, Republic of Ireland
The Role of the Internet in Academic Honesty: A Comparison of Engineering and Business Students
Paper presentation in poster format

Lynch, Raymond, Seery, Niall and Gordon, Seamus
University of Limerick, Republic of Ireland
The Formative Value of Peer Feedback in Project Based Assessment
6: Student Engagement & Learning Outcomes 17:10 - 17:30, Thu 1st, Boole 1

MacMahon, Cormac, Coleman, Maébh, Ledwith, Coleman, Cliffe, Brian and McGlone, Róisín
Institute of Technology Blanchardstown, NUI Galway, Dundalk Institute of Technology, Cork Institute of Technology & Institute of Technology Sligo, Republic of Ireland
Accelerating Campus Entrepreneurship (ACE): A Sectional Analysis of Practices to Embed Entrepreneurship Education into Engineering at Irish Higer Education Institutions (HEI's)
9: Innovation & Information Technology 15:00 - 15:20, Fri 2nd, Boole 1

McAfee, Marion and Reid, Stephen
Institute of Technology Sligo, Republic of Ireland
Challenges in Providing Practical Labs Online to Distance Learning Students
9: Innovation & Information Technology 14:40 - 15:00, Fri 2nd, Boole 1

McDermott, Rodney, Hegarty, Lynda & Strong, W. Alan
University of Ulster & North West Regional College, Northern Ireland
Reflections on Trialling Two Teaching Strategies for Sustainability Management Education in an Undergraduate Engineering Module
7: Teaching Sustainability 10:30 - 10:50, Fri 2nd, Boole 1

Mitchell, Kyle, McCune, Keith, Yablonsky, Gregory, Gharabagi, Roobik and Ray, Ajay
St Louis University, United States & The University of Western Ontario, Canada
Teaching a Course "Technology And Energy Around You"
Paper presentation in poster format

Naher, Sumsun, McMorrow, Denise and Brabazon, Dermot
Dublin City University, Republic of Ireland
Employer and Student Perspectives on Skills for Engineers in the Twenty First Century and Beyond
Paper presentation in poster format

Nobes, David, Stout, Curt and Ackerman, Mark
University of Alberta, Canada
The Impact of Senior Design Project Workload on Student Performance
6: Student Engagement & Learning Outcomes 16:30 - 16:50, Thu 1st, Boole 2

Ó Gallachóir, Brian
University College Cork, Republic of Ireland
Energy Engineering - a New Engineering Discipline or Simply a Pick and Mix?
5: Future Perspectives 16:30 - 16:50, Thu 1st, Boole 1

O’Dwyer, Aidan
Dublin Institute of Technology, Republic of Ireland
Analysis of Engineering Students Learning Styles on Level 7, Level 8 and Level 9 Programmes
Paper presentation in poster format

O’Dwyer, Aidan
Dublin Institute of Technology, Republic of Ireland
Experiences of Teaching, Learning and Assessment of Student Research Skills on a Level 9 Taught Programme in Engineering
4: Student Understanding 12:05 - 12:25, Thu 1st, Boole 2

Olsen, Stig Irving
Technical University of Denmark, Denmark
A Strategy for Teaching Sustainability Assessment
3: Engineering Ethics & Sustainability in the Curriculum 12:05 - 12:25, Thu 1st, Boole 1

Ožvoldová, Miroslava, Schauer, František and Beňo, Miroslav
University of Trnava & Constantine the Philosopher University, Slovak Republic & Tomas Bata University, Czech Republic
Remote Free Fall Experiment For Dynamic Studies
Paper presentation in poster format

Petruska, Jindrich
Brno University of Technology, Czech Republic
Introduction of Problem Based Learning to Mechanical Engineering Curricula
8: Problem Based Learning 10:30 - 10:50, Fri 2nd, Boole 2

Pieskä, Timo
Oulu University of Applied Sciences/Raahe School of Engineering & Business, Finland
Some Finnish Visions of Engineering Education
5: Future Perspectives 17:10 - 17:30, Thu 1st, Boole 1

Prabhu, Vittal and Yao, Tao
Pennsylvania State University, United States
Engineering Education in Service Systems
10: Developing Skills & Learning Outcomes 15:20 - 15:40, Fri 2nd, Boole 2

Pritchard, Colin
The University of Edinburgh, Scotland
Heat and Mass Transfer in the Long Rains: Doing Engineering Under a Mango Tree
2: Global Perspectives 09:30 - 09:50, Thu 1st, Boole 2

Purcell, Patrick, Dunnion, John and Loughran, Hilda
University College Dublin, Republic of Ireland
General Electives in Civil Engineering and Computer Science
Paper presentation in poster format

Queiroz, Ana
ESEIG - Instituto Politécnico do Porto, Portugal
Assessment of Student Based Learning Approach in Biomaterial Sciences
Paper presentation in poster format

Ramachandran, Sivakumar
Institute of Art, Design & Technology, Republic of Ireland
Engineering Education: Non-traditional Specialisms, and The Smart Economy
10: Developing Skills & Learning Outcomes 15:40 - 16:00, Fri 2nd, Boole 2

Ring, Denis and O'Leary, Raymond
University College Cork & GlaxoSmithKline, Republic of Ireland
The Role of Industry in Guiding the Pedagogy of Chemical Engineering Design
Paper presentation in poster format

Ring, Denis and Oliveira, Jorge
University College Cork, Republic of Ireland
Incorporating a 5S Structured Approach to the Planning and Delivering of a Final Year Design Project
1: Industry Perspectives 10:50 - 11:10, Thu 1st, Boole 1

Saha, Samir Kumar
Jadavpur University, India
Curriculum Design of Mechanical Engineering in a Developing Country
Paper presentation in poster format

Strong, Alan and Hemphill, Lesley
University of Ulster, Northern Ireland
Integrating Built Environment Studies Through Sustainable Development Education
3: Engineering Ethics & Sustainability in the Curriculum 12:25 - 12:45, Thu 1st, Boole 1

Strong, Alan, Woodside, Alan and McDermott, Rodney
University of Ulster, Northern Ireland
Sustainability Principles Provide a Framework to Facilitate Integration of Design Processes
Paper presentation in poster format

Tamtam, Abdalmonem, Gallagher, Fiona, Naher, Sumsun and Olabi, Abdul Ghani
Dublin City University, Republic of Ireland
English Medium Instruction (EMI) for Engineering Education in Arab world
and Twenty First Century Challenges
2: Global Perspectives 10:10 - 10:30, Thu 1st, Boole 2

Wade, Patricia and Sleator, Adèle
EirGrid plc., Ireland
Educating EirGrid's Power System Engineers to Facilitate a Sustainable Future -
a Partnership of Academia and Industry
1: Industry Perspectives 09:50 - 10:10, Thu 1st, Boole 1

Wang, Hui
University of Saskatchewan, Canada
A New Graduate Course Teaching Chemical Engineering in use of Renewable Resources
7: Teaching Sustainability 10:50 - 11:10, Fri 2nd, Boole 1

Willmot, Peter and Bamforth, Sarah
Loughborough University, England
Using Video Reports to Promote Active Engagement in Learning
9: Innovation & Information Technology 14:20 - 14:40, Fri 2nd, Boole 1

Yablonsky, Gregory, Gleaves, John and Fushimi, Rebecca
St Louis University, Washington University & Proteus Catalytic Systems, United States
Teaching Sustainability through Catalysis
7: Teaching Sustainability 09:50 - 10:10, Fri 2nd, Boole 1

Abstracts

The following are the abstracts of papers presented at ISEE2010 in alphabetical order, based on the lead author. Full papers will be available online at: http://www.ucc.ie/isee2010/papers.html

ISSN: 2009-3225

Abu-Jdayil, Basim, Al-Attar, Hazim and Al-Marzouqi, Mohamed.
United Arab Emirates University
Outcomes Assessment in Chemical and Petroleum Engineering Programs

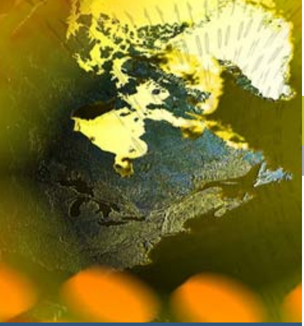
Abstract. This paper describes the establishment, revision and assessment process for educational outcomes of chemical and petroleum engineering programs. This process is initiated by defining the Chemical and Petroleum programs outcomes to match the ABET (A-K) EC2000 criteria since program outcomes are the most important part of the educational process and must foster attainment of program educational objectives. Then a variety of direct and indirect assessment tools are proposed to determine how well graduates from the both engineering programs are meeting the established outcomes. Three direct tools are implemented in the assessment process, namely; course / curriculum assessment, exit exam and capstone courses. The proposed indirect tools include internship advisor survey, course assessment by students, alumni survey, employer survey, students exit interview, and industrial advisory board. A schedule for collecting the assessment data to support the review of program objectives, outcome, and curriculum is recommended. The overall assessment of achievement of program outcomes is performed by averaging the proposed assessment tools using a weighting factor designed to provide some judgment on the importance, quality, and number of feedbacks of each tool. Programs details and the results of the assessment process for one cycle are presented in this paper. Application of the outcome assessment results in the continuous improvement of both programs is also addressed.

Adams, Karen, Ripper, Margie, Zander, Anthony and Mullins, Gerry.
The University of Adelaide
The Valuing of Creativity in the Workplace Roles of Engineering Doctoral Graduates

Abstract. This paper reports on a study that explored the beliefs of twenty-two industry-based employers of Mechanical and Chemical Engineering Higher Degree Research (EHDR) graduates about the value of these graduates to the engineering workplace. Once the commonly known generic employability attributes were set aside, the findings revealed that creativity was an essential factor in employers' decisions to accommodate these graduates. The employers' comments suggested that they valued knowledge and creative problem-solving skills gained in HDR candidature but feared that EHDR graduates would display attributes popularly associated with creative genius, and this concern reduced their willingness to accommodate these graduates. This highlights the value of creative skills and attributes, the hallmarks of HDR activity, to the overall employability of EHDR graduates in innovative enterprises, but reveals a barrier to industry engagement that is based on myth.

Adesina, Ayodeji and Molloy, Derek.
Dublin City University
Capturing and Monitoring of Learning Process through a Business Process Management (BPM) Framework

Abstract. In recent years, e-Learning systems have significantly impacted the way that we learn within universities, both in providing self-learning support and flexibility of course delivery. Virtual Learning Environments (VLEs) such as Moodle help facilitate the management of educational courses for students, in particular by helping lecturers and students with course administration. However, issues still remain; in particular e-learning environments provide a one size fits all approach to the learning process through the course materials - each student must follow the same learning path, regardless of their a priori knowledge, learning requirements or learning disability. Many commercial VLEs allow course writers to build courses as groups of lessons, but it is currently not possible to monitor the learning process of individual learners or learning groups through the course material in real-time. In order to solve the issues of a one size fits all approach; this paper discusses the development of a system that develops an adaptive learning process management system, using the concept of Service Oriented Architecture (SOA)



and Business Process Management (BPM). This system allows the course-writer to monitor the learning process of the learners in real-time and manually adapts the learning path or course materials. The paper also discusses possible future extensions to the work that would allow for the automatic adaptation of the learning path to meet an individual learner's needs. The paper concludes by discussing the benefits and limitations of our BPM implementation and discusses future extensions to allow for the automatic adaptation of learner's learning path.

Ahern, Aoife, McNamara, Martin, O'Connor, Tom and MacRuairc, Gerry.
University College Dublin

Critical Thinking in the University Curriculum

Abstract. This paper will describe a multi-qualitative study undertaken in University College Dublin to examine the issue of critical thinking as a graduate attribute. Critical thinking is a graduate attribute that many courses claim to produce in students. However, it is important to understand how academics define and describe critical thinking and whether their understandings of critical thinking differ, depending on their discipline or subject area. This study looks at how critical thinking is understood and realised in students in universities and examines how academics' understanding of critical thinking are realised in curriculum design.

The paper will describe a series of in-depth, semi-structured interviews with academics involved in teaching and learning in a number of disciplines, including engineering. The objective of these interviews is to look at how different disciplines define critical thinking and how they teach critical thinking in their courses. In addition the paper will describe the selection of modules which were considered to be particularly concerned with the acquisition and development of critical thinking were chosen, and the interviews carried out with module coordinators about the module design and assessment, recognition and measurement of critical thinking.

This paper will describe the outcomes of those interviews. While, the paper will describe how different disciplines view critical thinking, noting any differences in understanding and realisation of critical thinking in students, particular attention will be paid to the findings that relate to the engineering discipline. The paper will describe how engineering academics understand and define critical thinking and what pedagogical and assessment approaches are used in engineering to encourage critical thinking in engineering students.

Al-Attar, Hazim, Abu-Jdayil, Basim and Al-Marzouqi, Mohamed.
United Arab Emirates University

Assessment of Educational Objectives in Chemical and Petroleum Engineering Programs

Abstract. Within the Chemical and Petroleum Engineering (CPE) programs at UAE University, establishing and reviewing educational objectives is part of the assessment and continuous improvement cycle for the programs. This paper describes a process for the establishment and assessment of the educational objectives set by the CPE Department at the United Arab Emirates University. This process is initiated by defining the CPE programs outcomes to match the ABET (A-K) EC2000 criteria and from these outcomes the program educational objectives are derived. Next, the assessment tools are defined and these include Alumni and Employer surveys and special formats are prepared to achieve this purpose. The Alumni Survey is designed to provide the information needed by both programs to continuously measure the degree to which the concluded educational objectives are attained. The Employer Survey is designed to assess how well the graduates of the two programs meet the educational objectives from their employers' perspectives. The results of the two surveys are averaged using a weighting factor designed to provide some judgment on the importance, quality, and number of feedbacks of each tool. It may generally be concluded that the overall educational objectives of both programs have been largely met with average score for each objective between 4 and 4.4 out of 5.0 and that incremental enhancements could help achieve further improvements.

Alpay, Esat, Bull, Anthony and Ahearn, Alison.
Imperial College London
Cross-Departmental Initiatives for a Global Dimension in Engineering Education

Abstract. Issues of sustainable development, globalisation and poverty reduction have led to much discussion on the changing role of the engineer and, subsequently, engineering education. Within the UK, there is increasing acknowledgement of the need for a global dimension in engineering education to address current and future economic, social and environmental challenges. Many employers themselves are driving such a need through there efforts to attract and develop graduates which have an astute global awareness. At Imperial College London, the Faculty of Engineering has initiated a number of cross-departmental schemes to help support the broader, inter-professional and skills-focussed development of engineering students, and further place engineering in the context of societal priorities. In this paper, an overview of the cross-departmental schemes is given, and some initial evaluation data on their impact on the student learning experience presented. The schemes can be grouped into three areas: core-subject enrichment, new courses development and student-led projects. These are supported and facilitated by faculty-wide activities in learning technology. The central coordination of the schemes, but in close correspondence with departmental teaching and learning directors, has also helped instigate the developments and promote a culture of shared responsibility for engineering education which goes beyond the usual departmental boundaries. Examples will be presented to demonstrate the range of learning outcomes which can be achieved through such cross-departmental approaches, such as interdisciplinary communication, real-world engineering experiences, wider technical, social and ethical awareness, and both core engineering and engineering-in-context recognition. Specific schemes to be presented include: the Engineering Impact series of lectures; flexible timetabling for shared option courses across departments; a common framework for engineering ethics engagement; engineering mastery; large scale demonstration materials for mechanics teaching; mathematics and creative design support; and the set-up of a new academic role for the support of student-led projects.

Alzubaidy, Sarim.
Heriot-Watt University Dubai Campus
Integral Approach to Enhance Engineering Education in an Off Shore University Campus

Abstract. The relevance of engineering education to the needs of rapidly developing engineering industries in the Gulf region is of paramount importance. Heriot-Watt University has taken a lead in setting up a campus in Dubai to offer British education to students from the Gulf region and beyond. Conducted surveys have highlighted that the centerpiece of the skills most valued by employers in this part of the world are the engineering reasoning skills of graduates. This paper describes the development of applications in a BEng (Hons) degree course in Mechanical engineering to meet the need of local industry as well as equipping graduates with additional set of relevant skills that enable them to adapt to rapid changes of the local and regional economies.

Baha, Bahawodin and Katz, Tim.
University of Brighton
International Engineering Education and Partnerships with institutions in the developed World

Abstract. Engineering education has relatively a long history in Afghanistan but because of the instabilities in the country, this sector like other sectors, has experienced catastrophic destruction.
Several Engineering and Technical Vocational Educational (TVE) institutions were established in the capital and some other major cities. Most of engineering and TVE institutions, especially the successful ones, were established with the help of other nations

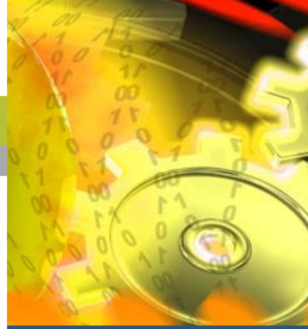
such as the US, the Germany and USSR.
This paper will discuss the history, present conditions and the progress of Engineering and institutions in Afghanistan. It has been recognised that the establishment of Engineering and TVE institutions is vital for the reconstruction efforts and future development in the country. Therefore, the ministry of higher education in Afghanistan has established partnerships between the Universities in Afghanistan to some universities in the developed world recently. The effectiveness of such partnerships will also be discussed in this paper. Furthermore, recommendations will be made as to improve the quality of engineering education in Afghanistan that will equip the young generation with skills that highly desirable in the country and to meet international standards.

Barrow, George, Heinemann, Robert and Hinduja, Srichand.
The University of Manchester
Manufacturing Engineering Education across Europe

Abstract. In the course of the FP6 Network of Excellence entitled Innovative Production Machines and Systems (I*PROMS) a comprehensive study was conducted investigating the manufacturing engineering education across several European countries, such as the UK, France, Germany and Italy. The main objective of this study was to gather information about the syllabi of both mechanical as well as industrial engineering courses at the undergraduate level (first degree courses) offered by the institutes concerned, and to determine the manufacturing-related content of these courses. Manufacturing in this context encompassed the four subject areas: production machines and machining; design; automation and control; and manufacturing management.
The research revealed that the minimum amount of manufacturing education provision, i.e. the content that is compulsory for the students taking a particular course, across the four aforementioned sub-groups is quite consistent, indicating that most, if not all, institutes attempt to give a broad coverage of manufacturing within their compulsory modules. It should be noted, however, that analysis on a subject group basis did not show the same level of consistency.
The research also revealed only a small reduction in design- and management-related subject areas between the maximum (taking into account all optional modules the students can take for a particular course) and minimum amounts of manufacturing education provision (only considering the compulsory modules). This indicates that these subject areas are seen as ‘key’ subject areas by the institutes concerned.

Bennett, Gareth, Kelly, Kevin, Collins, Ruth, Boland, Frank, McGoldrick, Ciaran, Pavia, Sara and O’Kelly, Kevin.
Trinity College Dublin
Implementation of Project Based Learning in a Large Engineering Programme

Abstract. The role of the engineer in industry has evolved, with today’s engineering businesses seeking engineers with abilities and attributes in two broad areas - technical understanding and enabling skills. Institutions within the engineering community such as Engineers Ireland, the Accreditation Board for Engineering and Technology, the Royal Academy of Engineering and members of the CDIO (Conceive Design, Implement, Operate) initiative have highlighted a need for new approaches to learning and teaching of engineering within our academic institutions.
This paper reports on the recent implementation of project based design courses in both of the two engineering programmes offered by Trinity College Dublin. The projects are each carried out in small groups (typically four to six) and are virtually free of podium based teaching. Initially, the students are provided with a design brief, foundation level technical input and raw materials. The projects are developed around the principles of CDIO which represents best international practice for teaching design. The implementation of this methodology requires self-directed learning, teamwork and small group learning, culminating in the actual building and testing of a prototype. Some projects finish with a public competition which tends to generate huge excitement. The new courses have been seen to foster innovation and to provide a format that channels the student’s creative skills



in a coherent and structured manner.
The detail of the courses, the learning outcomes, and the resource overhead are presented as well as a discussion on the initial results from the programmes.

Blaskovsky, Cintia, Portilho Camargos Gomes, Lucas and Alves Rodrigues Blaskovsky, Isabel Maria Cristina.
Universidade do Estado do Pará, Universidade de Itaúna & Universidade Federal do Pará
Comparative Studies on the Teaching of "Sustainability" in the Program Courses of Industrial Engineering from five Public Universities in Brazil

Abstract. The importance of exercising the learning related to sustainability emphasizes the justified interest in studying how the institutions in Brazil are building the teaching-learning process for the training of professionals capable of meeting the new challenges of working for sustainable development. To know how universities are organizing to form professional industrial engineering can promote sustainable development and the practical application of social and environmental responsibility in the labor market, we propose a comparative study of the programs and interviews with the coordinators. We selected five public universities in a geographical region of Brazil and analyzed the programs of courses industrial engineering. Interviews with teachers coordinators of the courses being studied to know your opinion on the theory and practice. The menus of the subjects were compared between the universities and the courses of teachers coordinators of these courses also identified aspects of the practice of the classroom. We note that a preliminary analysis indicates that higher education institutions surveyed in Brazil encounter difficulties in integrating theory and practice of sustainability to their students and future professionals in industrial engineering who will work for sustainable development.

Brabazon, Dermot
Dublin City University
Engineering Community of Practice Within the National Digital Learning Repository

Abstract. The Engineering Community of Practice plans and develops learning resources for sharing among Engineering lecturers at Third and Fourth Level in Ireland. This presentation will give an overview of the types of resources that are present, details on how to upload and download and information on funding that can be received to help develop these resources.

Brabazon, Dermot, Naher, Sumsun, Karazi, Shadi and Murphy, Gary.
Dublin City University
Analysis of International Graduate Programmes Structures

Abstract. This article traces the evolution of graduate study in Engineering in Ireland over three decades. Very few studies on statements of purpose have shown the different norms and structures of graduate programmes in Ireland. In this paper, clear reviews of traditional and structured PhD degrees were revealed in terms of credit requirements and coordination structures. The authors summarise the characteristics of graduate programmes in different universities in Ireland and compare these data to those obtained in some of the leading universities in Australia, Canada, USA and some European countries like France, Italy and UK. The implementation of graduate programmes in Ireland is very recent and the structure of running these programmes is different for different universities. Plans for enhancement of graduate programs and the development of new initiatives to support graduate student academic and professional development are very important for the success of this programmes. The growth in enrolment that reflects a broad diversity of students will require not only increased financial resources but an adequate and sound organisational structure in order to move forward. Graduate Programs in engineering determined that the successful applicants focused on research and professional experience and interests rather than theoretical experience, thus demonstrating a commitment to applied epistemology. In some universities, the Dean of research supervises and coordinates all aspect of graduate programmes while in other universities these are run by the Dean of

teaching. In some cases it is completely supervised by registry of the university. While the structure of running a university is completely different in some countries compared to Ireland such as Australia, Canada and USA, the focus was to explore the related modules and credits rather than direct structural comparison. In engineering graduate programmes in most cases have two types of modules are on offer; generic modules and subject specific modules. Reviewing of the past and current functions in the organisation and administration, examining modules on offer and credit rating of the graduate programme is accepted to improve understanding for setting-up, restructuring, expansion, and/or reduction of the graduate programmes.

Brose, Andrea and Kautz, Christian.
Hamburg University of Technology
Research on Student Understanding as a Guide for the Development of Instructional Materials in Introductory Engineering Courses

Abstract. At Hamburg University of Technology, we are engaged in (1) investigating student understanding of fundamental concepts in electrical and mechanical engineering and (2) using the results from this study to guide the development of instructional materials. In this paper, we present methodology and illustrate the process of research and curriculum development with an example from an introductory Engineering Mechanics course. Our analysis suggests that when combined with active learning techniques, instructional materials developed on the basis of research on student understanding can improve student learning.

Campos, Daniela M. S. and Queiroz, Ana C.
ESEIG-Instituto Politécnico do Porto
Project Teaching in Biomedical Engineering

Abstract. Bologna strategy endures and makes teaching a new challenge. Student based learning is difficult to achieve specially when their background is based on easygoing and on a knowledge learning bases.
This paper aims at discussing new approach to the teaching Biomaterials and Electromagnetism, using a student centred competence based learning. A semester project was proposed involving these two units in which students had to comprehend, do a critical analysis and propose improvement solutions of several (one each group) biomedical devices. The students rapidly bonded to the idea as the theme chosen would directly concur to their future work. They were also encouraged to draw a project plan and in every class a situation status would be made with each group and the developments achieved during the respective week analysed, from this brainstorming new ideas and solid solutions were drawn. Students learnt that two, at first, completely different classes had more in common than expected: both units were well integrated in the project, which gave them the sense that biomedical is really a wide spectra engineering and of what they will get in touch in “real life”, moreover they learnt that most of the time the first choices although wrong can make them go a long way. The outcome results of this project were fantastic as 14 in 15 students were approved. In fact the quality and solutions achieved at the end of the project overcame our expectations not only for the solution itself but also, and probably more important for the students enthusiasm and commitment.

Cleghorn, William and Dhariwal, Harpreet.
University of Toronto
Pedagogical Impact of the MEETS on the Delivery of Engineering Courses

Abstract. This paper presents an innovative practice based on the Multimedia Enhanced Electronic Teaching System (MEETS). The practice was developed and successfully implemented for a core undergraduate course in Mechanical Engineering on mechanics. The MEETS was rigorously designed in response to the growing need of effectively teaching courses with large enrolments, while still allowing demonstrations, which traditionally have been limited to smaller classes. The MEETS includes (i) two video projectors, (ii)

two document cameras, (iii) a personal computer (PC) for showing animations, and (iv) the Easel Paper Dispenser Display Adapter (EPDDA), which allows the lecturer to write lecture notes on an area of a letter sized sheet of paper. Images from the EPDDA are shown using one of the document cameras. The lecturer controls which images are shown on the video projectors.

Cole, Jonathan and Spence, Stephen.
Queen's University Belfast
First Year Fluids – Encouraging Student Engagement when the Class Size is Large

Abstract. Over the last six years, the authors have been responsible for a first year fluids course given to aerospace, civil and mechanical engineering students. The University had decided that these students should be taught as a single group for core first year courses and the class size has been around 250 each year. This paper aims to show how the teaching methodology was applied to the challenge of a large class and how student engagement was promoted.
There were normally two hours of lectures and one hour of tutorial each week for 12 weeks. The lecture style involved formal teaching interspersed with active learning elements, for example a short question/puzzle for the students to consider. The class was divided into small groups of about 25 – 30 students for tutorials; these ran simultaneously. A 10-minute test was held at the end of each tutorial during weeks 3 – 11. Each test contained five questions based on the previous week's lecture material and the marks contributed towards 20% of the module mark. It was a condition for passing the module that a student must pass at least six of the nine tutorial tests. Thus, the assessment was designed to encourage and maintain student involvement with the course. Each student also had to participate in three laboratory classes – these practical aspects supplemented the lecture material.
It is believed that the teaching was successful and the assessment strategy had the desired effect. Lecture attendance was good and student feedback confirmed the weekly tests were useful.

Cole, Jonathan, Price, Mark and Davies, Gary.
Queen's University Belfast
Developing Maths and Computing Skills in the Context of an Integrated Curriculum

Abstract. This paper describes a mathematics and computing module provided for second year aerospace engineering students enrolled on the MEng programme – typically about 20 students. While it has been important to develop students' skills in these areas, the opportunity has also been taken to enhance integration across the curriculum.

The maths section of the course involves more applied topics such as linear algebra, vector calculus and Laplace transforms. Examples relevant to aerodynamics and engineering dynamics are included. Active learning is prominent during the classes. In addition to formal teaching, students work through example questions with the lecturer observing and available to assist.

The computing section is based on Matlab and builds on an introductory Matlab course. It aims to demonstrate application of the maths and show the usefulness of computing tools in aerospace engineering. The content was carefully designed to relate to the maths section and other second year subjects. For example, student exercises include plotting lift distribution on a wing, performing some structural analysis and investigating eigenvalues, before the course climaxes in a mini project on wing design.

Students found the Matlab section to be challenging. However, encouraging feedback indicates that most learn a lot from the course, they observe the applications for the maths and note the relevance to their degree.

Collins, Ruth, Dyer, Mark, Robinson, Anthony and O'Kelly, Kevin.
Trinity College Dublin

Case Study on the Inaugural Design and Construction of a Refugee Shelter for Second Year Engineers

Abstract. This paper describes the development of a new design project for the second year of the Bachelor of Engineering Degree at Trinity College Dublin (TCD). The project comprises an open ended design and build exercise that integrates civil and mechanical engineering. The students are required to design a refugee shelter for an extreme climate with a number of requirements including the following: the shelter must be light weight and portable, it must be able to store food above ground, it must be able to collect and store water and it must facilitate a solar cooker. This is one of the few opportunities for the students to tackle an open ended design project with such a wide range of variables. The students work in teams of typically ten persons and are required to deliver a design report and poster presentation. The report must clearly show design concept, calculations, project management, health and safety and sustainability. Following a public exhibition of the posters, the top ten designs are selected for construction in the grounds of TCD. Teams are assessed on their ability to construct their own design, the robustness of the finished shelter and their project management throughout the day. This paper provides an overview of the design project and how it was facilitated. Furthermore, the problems with running a new design challenge for the first time are described in detail. Suggestions for improvements to the course are also provided.

Conlon, Eddie.
Dublin Institute of Technology

Towards an Integrated Approach to Engineering Ethics

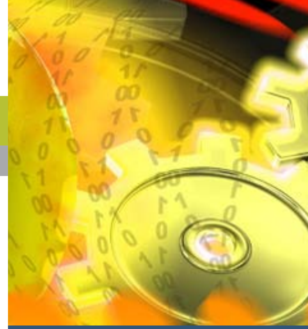
Abstract. There is an increasing diversity in approaches to teaching engineering ethics due to increasing dissatisfaction with the dominant approach which uses case studies focused on moral dilemmas confronting individual engineers. There has been a demand for a greater consideration of the organisational and social context in which engineers work and for a shift in focus from micro ethics issues concerning individuals to macro issues of concern to the engineering profession. Further, there has been a demand that engineers focus on societal decision making about technology and their role in policy development. Drawing on the work of the American sociologist George Ritzer which focuses on micro/macro integration and the subjective and objective dimensions of sociological analysis this paper provides a framework for understanding different approaches to engineering ethics. In moving towards an integrated approach it is argued that a key issue confronting engineers is how to change the economic and social context in which they work so that it enables rather than constrains the development of sustainable engineering solutions. It is also argued that an integrated approach should focus on integrating the different levels of analysis into accounts of ethical issues.

Cosgrove, Tom, Phillips, Declan and Quilligan, Michael.
University of Limerick

Educating Engineers as if they were Human: PBL in Civil Engineering at the University of Limerick

Abstract. The authors' experiences designing and implementing a new problem based learning (PBL) programme in civil engineering at the University of Limerick is described. Formal focus groups, student and staff learning logs, a variety of student assessment formats, tutorial dialogue and feedback techniques are used to build a picture of the staff and student experience so far. The authors reflect on their own extensive experience in both university education and professional training and mentoring.

Approaches to specific PBL challenges including trigger design, PBL process facilitation, and integration of learning across subject boundaries and group work assessment are also described.



Dearn, Karl David, Tsolakis, Athanasios, Megaritis, Thanos and Walton, Doug.
The University of Birmingham & Brunel University
Adapting to Engineering Education and Teaching Challenges

Abstract. The widespread reduction in teaching hours and increase in student numbers has resulted in pressure to reduce syllabuses. The increased number of students with varied cultural background and the need for multi-disciplinary teaching in order to reduce teaching duplication and costs, introduces the need for teaching innovation and teaching methods that are effective. Difficulties also arising in providing academic support particularly in tutorials. Even worse, a cultural situation is developing where the expected work levels for students is vague. This paper addresses these issues and looks at how syllabus contents in mechanical design and thermodynamics, core engineering modules can be retained by concentrating on student self learning. Three phases of student centred learning are proposed. First is the subject material itself and how this needs to be written and presented to the student. Engineering encompasses fast advances, new technologies and applications that need to be integrated within the modules, while still equipping students with fundamental knowledge as well as communication and interpersonal skills. The second is a preliminary tutorial system in which students, working in student centred learning groups, start by answering broadly based questions designed to test their understanding of the subject before attempting the third phase, that of solving traditional type tutorial questions. Educational advantages that merge traditional methods of engineering education delivery with new and innovative methods, are described in this paper. It also includes details on the deeper understanding exhibited by students, illustrates a greater student involvement and enhanced tutorial support, as well as staffing implications and problems encountered.

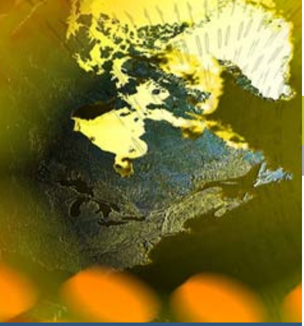
Dobis, Pavel, Bruestlova, Jitka and Bartlova, Milada.
Brno University of Technology
Curie Temperature in Ferromagnetic Materials and Visualized Magnetic Domains

Abstract. The Curie temperature is a physical constant and refers to a characteristic property of ferromagnetic materials. Above the Curie temperature, a material loses its ferromagnetic properties. In a ferromagnetic material, elementary dipoles are aligned into the so-called domains and the domains - through their arrangement - bring about the internal magnetic field of the material - magnetization. At temperatures above the Curie point the ordered state is destroyed, magnetic dipoles become chaotically disordered and the material no more exhibits ferromagnetic properties. This change comes about in an abrupt manner at reaching the Curie temperature.

The paper describes a laboratory experiment intended for undergraduate students of Electrical Engineering. In the course of the measurement, students determine the Curie temperature of iron. In order to facilitate the understanding of this phenomenon, domains are visualized and observed in a microscope under variable external magnetic field.

Duffy, Gavin and Bowe, Brian.
Dublin Institute of Technology
A Framework to Develop Lifelong Learning and Transferable Skills in an Engineering Programme

Abstract.
Aims
Highlight the need for development of non-technical skills to facilitate integration of engineering and sustainability. These include reflection, lifelong learning, self-directed learning, information literacy, critical thinking, creativity, problem solving, communication and group work skills. These should be integrated with the technical content and developed in a structured manner, just like discipline knowledge is developed from introductory to advanced. This will result in a balanced integration of sustainability and engineering. This paper presents a strategy to address this.



Content
A justification for this strategy is provided. Parallels to community based learning models are presented to illustrate the need to intend, rather than aspire, to include sustainability. This requires a more reflective approach. The engineer sees him/her self as a lifelong learner who has the ability to plan ahead, develop and find better ways to solve problems and move from weak to strong sustainability. The framework presented requires a move to a group-based project driven approach with a structure for the development of non-technical skills. In first year group work, reflection, personal learning style and accepted learning cycles are introduced. Reflection is started and advanced to self assessment in the middle stages. A growing independence in self directed learning and information literacy occurs. They should finish as independent lifelong learners who can observe, analyse and evaluate performance and plan ahead.

Conclusions
This framework can be implemented. Non-technical skills should be integrated with technical content. Sustainability is better served by shifting emphasis from aspirational to intentional. Reflection is needed to facilitate a holistic approach to engineering as required for sustainability.

Dunphy, Louise and O'Dwyer, John.
Waterford Institute of Technology
Innovative Technologies: The Educational Challenges

Abstract. The creation and sustainability of a Smart Economy will require that Innovative Technologies be embraced by key stakeholders. It is therefore imperative that the engineering and scientific communities in both academic and industrial arenas be sufficiently well informed regarding the advantages and limitations of such technologies.

Innovative Technologies are frequently underpinned by fundamental advances in Materials Science and Engineering as evidenced by the development and application of bio-inspired smart materials and structures. The goal of the activities being reported here is to demonstrate how a problem-based learning approach can be used to enhance learning of key concepts for this evolving class of materials. A significant component of this work will feature the integration of technology into PLB so as to create a more flexible and effective learning experience. The ultimate goal is to enhance the understanding of, and confidence in, smart materials and structures with a view to their application in a number of industrial sectors including medical technologies and healthcare.

Dwyer, Brian and Byrne, Edmond.
Energetics Pty. Ltd and University College Cork
Practical Skills and Techniques for the Transition to a Sustainable Future, a Case Study for Engineering Education

Abstract. Sustainability has been a live issue since the late 1980's with significant focus on Environmental & Sustainable Design. Transition to a sustainable economy requires organisations to move from current operational models to the sustainable delivery of products and services, as well as the development of new service offerings.
This paper seeks to identify the skills and disciplines that have been and continue to be deployed in taking organisations on this transitional journey. To achieve this, a case study involving Energetics Pty. Ltd., a leading Australian multi-disciplinary consultancy specialised in engaging public and private organisations in the development of their responses to climate change and sustainability is described.
The aim of the paper is to establish which aspects of their university education practitioners have deployed in devising and implementing sustainable solutions for their clients. These aspects could range from the understanding of industry's specific technologies and systematic thinking, to communications skills and stakeholder engagement.
The paper will finally put forward recommendations regarding which aspects should be

incorporated or reinforced into engineering courses, to enhance the ability of graduate engineers in transitioning their future employers towards the sustainable future of their organisations.

Early, Juliana, Murphy, Adrian and McCartan, Charles.
Queen's University Belfast

Bridging the Gap - An Active/Interactive Approach to Introductory Aerospace Design Education

Abstract. The transition from the classroom based educational structure to the university experience can prove to be a challenging experience for 1st year engineering students. Many initiatives have highlighted the benefits of engaging students in a problem based learning (PBL) environment, and over a number of years, Queen's University Belfast have worked towards embedding this principle into the teaching of Aerospace Design within both the BEng and MEng Aerospace Engineering degree programmes through the CDIO intiative.

An introductory module, Introduction to Aerospace Engineering, has been specifically developed to bridge this gap between the traditional school-based learning experience and the independent thought and critical analysis required with the university environment, complimented with a number of the key professional engineering skills of teamwork, presentation and reporting required by society today.

The module content is focused on providing the students with a platform to develop a deeper understanding of the theoretical principles taught in traditional engineering subjects (specifically flight mechanics, materials, solids and structures, engineering mathematics and fluid mechanics) in a purely hands-on exploratory environment. This is aimed at enhancing the engagement and enthusiasm of the students for the subject matter, while simultaneously providing context for some of the more abstract theoretical principles.

This paper highlights the teaching and learning outcome concepts for the module and the assessment practices embedded into it and explores how the active/interactive approach to Aerospace design can enhance the learning experience for the students and create a stimulating environment for engineering discovery.

Ebenhack, Ben and Martinez, Daniel.
University of Rochester & University of Southern Maine

Qualifying Energy's Value to Future Engineers and Scientists

Abstract. Using our academic research and teaching modules for chemical engineering and environmental science undergraduate students, we present a method for laying a foundation for students to understand energy's value in the 21st century more robustly and within the context of both the developed and the developing world. In this paper we argue that coming transitions will be supported primarily not by new technologic inventions or discoveries, but by matching systems to consumption patterns and vice versa. It will be a societal transformation, which relates to limits, timeline, and geo-social context. First, we present data on the saturation-like character of the relationship between human development and energy consumption, and couple this with a Maslovian assessment of the pyramid of human needs. Second, we engage students to explore the role of alternative energy solutions, to also understand the values the energy systems seek to meet, which is a function both of where the society is on the energy versus human development curve and of timeline issues. Third we address timelines as they relate both to issues of depletion and to technologic maturity and urgency. Just as the depletion place limits on the sustainability of fossil fuel-based energy systems, technologies that require fundamental science breakthroughs are unlikely to be solutions to imminent shortages. We need to understand the realistic range of peak oil occurrence timing in juxtaposition with an understanding of the time-to-market of alternative energies. This equips engineering students to bring their technical expertise to bear on qualitative problems of human development.

Faleye, Sunday and Mogari, David L.
University of South Africa

Method of Teaching Fluid Mechanics in some South African Universities and Its Implications for Learning

Abstract. This study investigates the current method of teaching fluid mechanics and its implications for learning in undergraduate mechanical engineering classes in some South African universities. Open-ended questionnaires, classroom observation, and semistructured interviews were used to gather qualitative data from both students and lecturers in this field. The result revealed that fluid mechanics is taught in a traditional form using Microsoft PowerPoint slides, textbooks and blackboard. It also emerged that this method of teaching constituted learning difficulties for learners in some aspect of the fluid mechanics module. This study serves as a springboard for the bigger study which measures the effect of introducing computer animated instruction into the teaching of fluid mechanics in South African universities.

Fitzpatrick, Colin.
University of Limerick

Integrating Environmental and Social Considerations in the Curriculum of Undergraduate Electronic and Computer Engineers

Abstract. This paper will provide an overview of two problem based learning modules in the Department of Electronic & Computer Engineering at the University of Limerick which viewed together aim to give a rounded perspective on sustainability as it might apply to graduates in these disciplines.
The first of these is a second year module entitled “The Engineer as a Professional” dealing largely with engineering ethics and the evolution of codes of ethics, the role of the engineer in society and engineering responsibility. This module is examined using continuous assessment and is divided into ten problems or case studies that the students must solve in groups of three or four and make presentations to the class on the outcomes of their work. The assessment also requires the students to keep a reflective blog. Through problem solving the students are challenged to examine their own perceptions of an engineer’s role and the social impacts of engineering, while giving them a basic foundation in ethical theory and an overview of the competences of professional engineers as outlined by Engineers Ireland. These problems will be discussed in more detail in the final paper.
The second of the modules is a fourth year elective entitled “Electronics & the Environment”. Again, this module is examined using continuous assessment, comprised of approximately ten problems, worked on in groups of three or four. The presentations and blog are also required. The problems cover topics on sustainable development, life cycle thinking, life cycle assessment, streamlined life cycle assessment, and other problems and design case studies in the electronics and ICT area. These problems will be discussed in more detail in the final paper.
Finally, the paper will discuss the role that Engineers Ireland accreditation process had in initiating these modules and will also contemplate how the transition of engineering courses to be ECTS compliant as well as how the new five year professional accreditation requirements will influence developments in this area.

Flynn, Raymond and Barry, John.
Queen’s University Belfast

Teaching Ethics to Civil Engineers: Interdisciplinary Reflections

Abstract.
AIM: This paper aims to explore attempts in the Queen’s University Belfast undergraduate teaching programme to integrate ethical issues into the Civil Engineering curriculum.

CONTENT: Drawing on the Royal Academy of Engineering Statement of Ethical Principles,

we reflect on our experience as academics located in different schools and disciplines (Philosophy / Politics, Civil Engineering) working together in teaching Engineering Ethics to second year undergraduate Civil Engineering students within the wider framework of a module teaching the students communications skills. From an explicitly interdisciplinary perspective, ethical issues for engineers, including sustainability issues, were introduced to students via a lecture, and further developed in interactive class-based and group-based discussions and projects. The effectiveness of the programme has been evaluated by testing the learning of students in relation to the depth of understanding they gained from this interdisciplinary teaching collaboration as well as integrating reflection on student feedback. This paper discusses the changes that were made to this section of the module over a two year period and whether these changes - specifically in relation to presenting more case-studies and more practical examples rather than 'ethical theories' - improved the students learning.

CONCLUSION: This paper concludes with observations about what can be learnt from our experience in teaching a subject to students who have had no formal exposure to humanities for between three to seven years. We assess the potential utility of our findings for other courses which seek to embed knowledge and understanding of professional ethical codes in Engineering education and practice.

Foley, Aoife M. and Leahy, Paul G.
University College Cork
The Role of the Professional Engineer in the 21st Century

Abstract. In light of the current world economic and environmental crisis due in part to unsustainable development and poor financial planning, 21st Century engineers are faced with unprecedented challenges of developing a sustainable world in balance with the forces of nature to combat global environmental, social and economic crises. The European Union, the United States of America and a number of other countries have identified that smart solutions and highly skilled professionals are needed to survive climate change and create long-term prosperity. In this paper the evolution of the changing career of the engineer will be presented. The policy background to the current system of engineering education at bachelor's and graduate level in Ireland will be introduced and perceptions of engineering as a profession by society in general, and by school leavers selecting third level courses will be discussed. The role of the engineer as a specialist, expert or generalist will also be studied in terms of the changing demands and needs of society. Finally the responsibility of universities, through broad-based multidisciplinary teaching and training, to prepare the next crop of engineers will be examined.

Frazer, Victoria, Early, Juliana, Cunningham, Geoffrey and Murphy, Colette.
Queen's University Belfast
Implications of Secondary Level STEM Education on Engineering Student Recruitment

Abstract. In 2009, the Department of Education and the Department of Employment and Learning (NI) jointly issued a report highlighting the challenges which were faced in ensuring that the supply of Science Technology, Engineering and Mathematics (STEM) qualified individuals continued to grow in response to the demand within the local economy. Over the past decade, there has been a steady decline in the uptake of secondary level STEM education, and based on workforce demand in the STEM sector (taking into consideration low forecast economic growth in the current climate), there is still a significant predicted shortfall in supply relative to demand over the next decade.

The report presented a series of 20 recommendations for action to promote renewed economic growth through STEM, and highlighted shortfalls in STEM education and careers advice particular to the Northern Ireland education sector. These reducing numbers have significant implications for the recruitment of a new generation of student engineer (and, by implication, the sustained development of the private engineering sector), so research

in Queen's University Belfast is examining some of the implications of the findings of this report, and looking at the drivers which influence subject choice at the pre and post-16 level.

The paper will present an analysis of the NI STEM report findings from the perspective of a tertiary level engineering school, and the impact of these findings on the recruitment and retention of high calibre students into the engineering discipline.

Gibson, Peter and Childs, Peter.
University of Wollongong

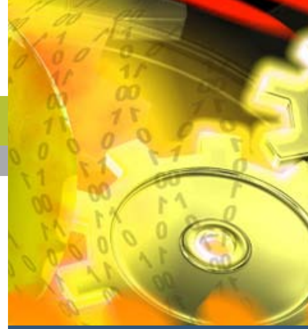
Graduating Professional Engineers and Management Skills – Are they Adequate for the Workplace?

Abstract: This paper considers the notion that for the majority of engineers, the development of managerial skills will be essential and cannot be 'picked up on the job'. Engineers will, increasingly need to understand the interaction of design with quality, sustainability, commercial and product planning, organisation, management of people, team work and finance. This paper considers the need to develop managerial skills and will report the results of a survey carried out to cover a range of firms and government bodies that employ graduate engineers.
Engineers are finding they need to take on more complex tasks that include very significant managerial issues. Most engineering faculties have attempted to teach managerial skills in their engineering curricula. However, management has often been viewed as secondary to technical skills and hence does not encompass the integrated range of skills needed. This paper considers some of the contemporary literature on teaching management to engineers. Some ideas are discussed, outlining research that is being carried out and reported by the authors, aimed at documenting current shortcomings with a view to developing a more effective future strategy for engineering management education.

Glassey, Jarka.
Newcastle University

Sustainability: Words or do we really Teach the Engineers Effectively?

Abstract. Sustainability is an important concept of engineering education and methods of embedding it into curriculum are continuously sought. The Institution of Chemical Engineers 'sees sustainable development as the most significant issue facing society today' (http://www.icheme.org/sustainability/) and places great emphasis upon the embedded learning of sustainability within the curriculum, as evidenced in their new accreditation guidelines. Newcastle University was amongst the first to gain funding from RAE for a Visiting Professor in Principles of Design for a Sustainable Environment. This led to the development of a number of case studies used in the education of engineers.
This contribution will describe the efforts at CEAM to embed sustainability into curriculum from week 1 of chemical engineering curriculum. These include a week long module of introduction to chemical engineering in the first year, a number of industrially relevant case studies within Enquiry Based Learning (EBL) that have a great societal impact. Details of the transition towards EBL, development of the case studies on fuel cell effectiveness and sustainable plant design will be provided. Emphasis will be placed on the methods of assessment of student learning as well as methods of evaluating the effectiveness of delivery using case study approach. Student focus groups and diamond ranking confirmed that students perceive the case studies as very important and prefer developing their skills of sustainable design in realistic setting. Detailed analysis of the results will be presented together with an indication of the impact of EBL upon student learning power.



Grepl, Robert.
Brno University of Technology

Problem Based Learning in Mechatronics

Abstract.
AIM: In this paper, the experience with teaching students of mechatronics with the use of practical laboratory models is introduced. All main steps from system modelling to its control are described.

CONTENT: Mechatronics combines the knowledge of mechanics, electronics, computer control and programming into the one technical product. Such a wide scope of issues, problems and questions to be learned and taught comprise an interesting challenge for both students as well as teachers.

The education in our Mechatronics laboratory is based on practical use of several laboratory models starting from simple and linear DC motor with incremental encoders through nonlinear magnetic levitation model to the MIMO nonlinear helicopter model or strongly nonlinear real-world automotive electronic throttle.

During the exercises of several bachelor and master courses students perform following tasks: modelling and parameter estimation or system identification based on measured data; design of linear controller (PID, LQR); design of state estimator; nonlinear controller design. Often they gain their first experience about the real systems and find that nonlinearities such as dry friction can significantly complicates the controller design.

The real-time control is based on Matlab/Simulink tools. With the RT Toolbox the student can control e.g. the DC motor in several minutes with only previous knowledge of Simulink. For advanced task the single board dSPACE hardware is used.

CONCLUSION: Several practically oriented bachelor and master thesis confirm our belief, that real educational models can be challenging for the students and can motivate them.

Hermon, Paul and McCartan, Charles.
Queen's University Belfast

Assessing the "Softer Skills" Learning Outcomes in Group Projects

Abstract. The Product Design and Development and Mechanical Engineering degree programmes in the School of Mechanical and Aerospace Engineering at Queen's University Belfast include major group Design Build and Test (DBT) projects in their 3rd and 4th years of study. These are advanced team projects which combine the technical and commercial elements typically found in industry. The students start with the identification of a problem and then develop a product through concept, product design specification, detailed design, prototyping and testing stages to finally produce plans for manufacture and commercial launch.
These year long projects seek to develop the students' skills and abilities across all phases of a product lifestyle and as such have a wide range of learning outcomes. Many of the learning outcomes are capable of being assessed through traditional means, such as written reports, but other "softer skills" such as time management and team working skills are less easily assessed in this way. Academic staff acting as supervisors of such projects cannot be with the students all of the time, particularly since they are often required to simultaneously supervise multiple projects as well as carry out research and perform other teaching and administrative roles. The potential to observe the operation of project groups over a long period of time and hence assess these "softer skills" is therefore reduced.
This paper will detail some of the methods used at Queen's to assist in the assessment of "softer skills" learning outcomes and evaluate their effectiveness in terms of time efficiency, accuracy and reliability.

Hermon, Paul, McCartan, Charles and Cunningham, Geoff.
Queen's University Belfast

The use of CDIO methodology in creating an integrated curriculum for a new degree programme

Abstract. The School of Mechanical and Aerospace Engineering at Queen's University Belfast introduced a new degree programme in Product Design and Development (PDD) in 2004. As well as setting out to meet all UK-SPEC requirements, the entirely new curriculum was developed in line with the syllabus and standards defined by the CDIO Initiative, an international collaboration of universities aiming to improve the education of engineering students. The CDIO ethos is that students are taught in the context of conceiving, designing, implementing and operating a product or system. Fundamental to this is an integrated curriculum with multiple Design-Build-Test (DBT) experiences at the core.

Unlike most traditional engineering courses the PDD degree features group DBT projects in all years of the programme. The projects increase in complexity and challenge in a staged manner, with learning outcomes guided by Bloom's taxonomy of learning domains. The integrated course structure enables the immediate application of disciplinary knowledge, gained from other modules, as well as development of professional skills and attributes in the context of the DBT activity. This has a positive impact on student engagement and the embedding of these relevant skills, identified from a stakeholder survey, has also been shown to better prepare students for professional practice.

This paper will detail the methodology used in the development of the curriculum, refinements that have been made during the first five years of operation and discuss the resource and staffing issues raised in facilitating such a learning environment.

Joyce, Tom.
Newcastle University

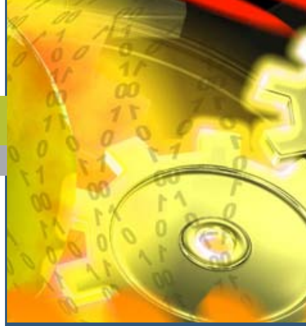
Use of Web-based Software and Joint Models to Teach Anatomy to Engineering Students

Abstract.
INTRODUCTION: Human anatomy is a complex subject but how can engineering students with little formal background knowledge be quickly taught this intricate and new topic and its associated language? Anatomy could be viewed as a dry, difficult and peripheral subject by engineering students. Therefore an aim was to use multiple, hands-on and interactive methods to help students to learn anatomy quickly.

METHODS: Innovative teaching materials in the form of web-based anatomical software and human joint models were introduced into a Masters level bioengineering course two years ago. In the current year a visit to an anatomy lab was added and, based on student feedback, more dynamic models of human joints were purchased and introduced. For the software and the models bespoke teaching documents, which students worked through in pairs or small groups, were produced by the author.

RESULTS: Student feedback has been collected over two academic years and has been equally positive about learning from the software and the models of human joints. In addition the author noted that students appeared to interact well with the teaching materials and the small group working encouraged discussion and sharing of opinion.

DISCUSSION: At approximately £4,400 (€5,000) for one year's access for ten seats, the software is expensive. Combining the positive learning benefits of non-hierarchal, small group and peer-to-peer learning with innovative and novel teaching aids quickly and effectively enhanced the student learning experience of atypical material by a cohort of engineering students.



Joyce, Tom and Dunne, Nicholas.
Newcastle University & Queen's University Belfast

A Comparison of Interactive Teaching Methods used in Bioengineering/ Biomaterials Modules at Two Russell Group Universities

Abstract. Internationally, biomedical engineering is a rapidly growing field and this is mirrored by an increasing number of dedicated degree courses being developed. The teaching of such multi-disciplinary material to engineering students brings challenges and opportunities. A comparison of interactive teaching methods on bioengineering and biomaterials modules at two Russell group universities was undertaken. Each module was taken by fourth year MEng students as well as taught MSc students therefore cohorts were similar in this respect, as were student numbers. Another similarity is that these modules are not part of bioengineering or biomaterials degrees, but options of mechanical engineering and materials degree programs. At each university, techniques included invited industrial lectures, small group assignments and presentations, alongside traditional lecturing practice. Student feedback showed that the range of teaching approaches were positively received and appreciated.

Joyce, Tom, Evans, Iain and Pallan, Bill.
Newcastle University

An Engineering Design Course: Developments over Five Years Emphasising Topics of Sustainability

Abstract. Background – Engineering design is a core subject in many Engineering departments and is greatly valued by future employers. Over five years a second-year engineering design course has been nurtured to focus on developmental projects associated with sustainability which emphasise hands-on learning.
Methodology – Students work in groups, with recent projects focusing on the design of domestic scale wind turbines. The design is taken from concept through manufacture to final testing using a wind tunnel. The commercial and societal relevance of the project is emphasised, as is the need for team working. Each team is given a budget of £100. The majority of the timetable is devoted to laboratory sessions where hand and power tools are available. Assessment methods include presentations, formal reports, 'weekly updates' and individual logbooks. Learning outcomes are based on UK-SPEC.
Benefits – Creativity and innovation are encouraged throughout the design process. Regular assessment occurs throughout with an emphasis on rapid, formal feedback.
Evidence of Success – Student feedback improves year on year with typical student attendance above 90%. The number of students taking the Design degree stream doubled last year.
Reflections – The key features which have led to success are allowing students to take a paper design through to manufacture (encompassing the hands-on and 'realistic' aspects of engineering) and trusting in students' creativity. Both areas led to students having a sense of ownership of their learning and developing into professional engineers. Assessment workload for staff is high but is seen by students as evidence of staff commitment to their learning.

Kapranos, Plato.
The University of Sheffield

Embedding 'Learning & Thinking styles' into Engineering Materials courses

Abstract: An area identified as useful for both staff and new students is 'Learning & thinking styles'. The majority of new students join the department being used to teaching styles that might be totally different to those they encounter in their first year at University. In addition if they are not aware of the different styles of teaching & learning they could potentially find themselves overwhelmed by any apparent lack of 'understanding' or failing to make the 'connection' with a subject.
Providing new students with awareness of their particular learning styles we hope to help them overcome any possibilities of 'mismatch' with the way various subjects being taught,

as well as support them in improving on the weak sides of their learning capabilities. This is seen as part of the overall process of educating the ‘complete’ engineer, ‘Broad minded, ethically and ecologically responsible agent of social and material change towards a socially just and ecologically sustainable world’, not only in demand by industry but an absolute necessity for our societies when facing up to the challenges of the 21st century.
Having done this kind of work as part of research into ‘Teaching and Learning’ over a period of nine years with 1st year tutees, the process was not formalised until now. The paper presents the results from the experience of running this scheme as part of an Introduction Week & Skills Week combination and discusses any possible benefits from embedding ‘Teaching and Learning’ as seen through personal feedback from students.

Kapranos, Plato.
The University of Sheffield
Cradle to? Introducing ‘Environmental Issues’ into the Teaching of Engineering Materials

Abstract: In a recent restructuring of subjects taught in the Materials degrees during the 1st year of studies, it was decided to introduce a module that dealt with Environmental issues. The module was aptly named ‘Cradle to? - Materials and the Environment’ and was delivered through 24 lectures and 3 tutorial/problem classes in the course of a semester.
As a module with content very pertinent to current issues and prominent in the public arena and media, the course has received unexpectedly mixed reviews having run for the first time in 2009. The module somehow failed to capture the imagination of the undergraduates against the expectations of the members of staff that put it together. We look into the possible reasons of why this might have happened and propose ways to rectify the negative aspects as experienced by the students who took the module.

Kapranos, Plato.
The University of Sheffield
Entrepreneurship & Innovation in Materials Engineering

Abstract: Having developed a module on Creativity, Innovation, Enterprise and Ethics, that reflects the continuous drive to educate the all round engineers highly sought after employers, and run it over 9 years, we have collected enough evidence on both the validity of such efforts as well as their effectiveness in achieving their goals.
This paper summarises the cumulative experiences of developing and running this module over the years and discusses possible future directions.

Kieran, Patricia, Malone, Dermot and O’Neill, Geraldine.
University College Dublin
Peer-assisted Tutoring in Chemical Engineering - Development of a Tutor-oriented Module

Abstract. A system of peer-assisted tutoring was introduced to the curriculum for a 4-year, professionally-accredited degree programme in Chemical Engineering. The system involves small-group, peer-assisted tutorials (PATs) associated with specific modules. PATs were initially developed to support a core 3rd Year module in Unit Operations. For the initial pilot series of PATs, Tutors (4th Year Chemical Engineering students) were remunerated for their efforts. The PATs provided Tutees (3rd Year students) with structured opportunities to work together, solving lecturer-defined, course-related problems, facilitated by slightly senior (4th Year) students. Tutors received training in directed-questioning and group facilitation and were supported with the relevant course material. The pilot series of PATs was positively received by Tutors and Tutees, with definable benefits for both groups. Based on the success of the initiative, a 5-credit elective module (CHEN40430: ‘Peer-Assisted Tutoring in Chemical Engineering’) has been developed for 4th Year Chemical Engineering students. For this module, the PATs system has been expanded to include another core, 3rd Year module, in Computational Methods, where PATs are implemented as computer-based sessions. This paper reports on the development and

initial implementation of the Peer Tutoring module, with specific reference to Tutor-based elements and to Tutor experiences. Tutors reported improved understanding of the relevant engineering principles, increased confidence in group facilitation and a sense of satisfaction in supporting others in their learning. There is potential for implementation of the system in other Engineering curricula.

Lambert, Chris and Rennie, Allan.
Lancaster University
Placing Postgraduate Research Students at the Heart of Knowledge Exchange: Benefits for Academia and Industry

Abstract. This paper describes the process of establishing an industry-driven Postgraduate level research degree programme that embedded the values of knowledge exchange (KE), particularly business support, without losing academic rigour. This aim was achieved by placing research students at the heart of KE as a discipline whilst undertaking leading research that would be of direct, tangible relevance to industry, ensuring that research activity was user-driven. The activity was focussed geographically in England's North West (NW) Region allowing it to dovetail with the priorities of regional economic growth initiatives, and particularly, those of a technical nature delivered through Lancaster University. These programmes work primarily with Small to Medium Sized Enterprises (SMEs) and so the development of the research degree programme had to accommodate these requirements, unlike conventional (taught) industry-based degrees that can work largely with multi-nationals and other corporate organisations.

The paper further outlines the innovative MSc (by Research) programme that has been piloted by Lancaster Product Development Unit, the KE team for the Engineering Department at Lancaster University. It demonstrates how industry focussed problems have been addressed to varying extents by the utilisation of several research-focussed Masters-level degree students. It further highlights how economies, educators and students can all benefit from Postgraduate degrees delivered from within a KE environment. The paper finally goes on to conclude that whilst added resources are required over traditional and more established degree schemes, that very effective outcomes can be obtained, capitalising on the tailored nature of the processes and methods of delivery.

Ledwith, Ann, Risquez, Angelica and O'Dwyer, Michele.
University of Limerick
The role of the Internet in Academic Honesty: A Comparison of Engineering and Business Students

Abstract. This paper explores students' attitudes towards the use of the Internet as a source for academic material and the ability of students to identify when a reference is necessary in using such material. The Internet presents both benefits to students in terms of access to information but also the temptation to pass off such information as original work. This study contributes to literature by firstly contrasting students' self-reported behaviours and views, with their ability to recognize and avoid plagiarism, and secondly comparing the behaviour and views of students from engineering and business courses.
A questionnaire which combines self-reported data with behavioural measures was administered to undergraduate university students. Analysis of the data shows that self-reported views did not transfer into behaviour, as students failed to recognize an example of plagiarism as a breach of academic guidelines although they were able to indicate when a reference was required.
These results highlight the need to enhance academic guidelines on plagiarism especially when the Internet is used as a source of information. This study suggests that students' understanding and awareness of plagiarism are directly related to experiential learning rather than relying on abstract statements and definitions in academic handbooks. The results also suggest that engineering students are more likely to use the Internet as a source of material without citation than business students, and that they are less likely to have received any teaching on academic honesty. Finally, the results highlight the potential

unsuitability of using self-report measures to study plagiarism, despite widespread use in the literature.

Lynch, Raymond, Seery, Niall and Gordon, Seamus.
University of Limerick
The Formative Value of Peer Feedback in Project Based Assessment

Abstract. This Study investigates the impact of peer feedback used as an instructional strategy to enhance undergraduate student learning in project based coursework. While peer feedback has been demonstrated to support students' learning in traditional classrooms, little is known about the efficacy in a project based learning environment. This study aims to examine undergraduate students' perceptions of the value of giving and receiving peer feedback, specifically related to a project based learning activity. In addition, the impact of that feedback on students' satisfaction with the project based module they undertook and on their thinking skills, based on Bloom's taxonomy, was also investigated. In order to explore this impact a comparative analysis was conducted with a concurrent module that students completed which acted as the control. Results suggest that the quality of students' reflections through peer feedback and overall satisfaction with the module remained high despite students' preference for instructor feedback. Students noted that peer feedback can be valuable and, more importantly, described how giving feedback not only reinforced their learning but enabled them to achieve greater awareness of the strengths and weaknesses of their own project.

MacMahon, Cormac, Coleman, Maébh, Ledwith, Coleman, Cliffe, Brian and McGlone, Róisín.
Institute of Technology Blanchardstown, NUI Galway, Dundalk Institute of Technology, Cork Institute of Technology & Institute of Technology Sligo
Accelerating Campus Entrepreneurship (ACE): A Sectional Analysis of Practices to Embed Entrepreneurship Education into Engineering at Irish Higher Education Institutions

Abstract. Aims: The Accelerating Campus Entrepreneurship (ACE) initiative, a Strategic Innovation Fund collaboration, is aimed at producing technology graduates who would not only have the entrepreneurial competencies to be more creative and self-confident in whatever they undertake during their careers but in time to master the skills for new technology start-ups and become employers in the innovation economy.

This paper investigates the cross-campus approach taken by ACE to facilitate entrepreneurship opportunities for engineering students in a way that leverages the commercial competencies of campus innovation centres, the business-plan competencies of the Business School and the product and technology development competencies of the Engineering Schools.

Content: ACE research was conducted on a case-study basis across the institutes of technology and universities nationally, taking a multi-stakeholder perspective from students, academics, institute management, technology transfer offices and campus incubator start-ups. While the individual case-studies are useful, their cross-referencing provides a valuable benchmarking insight into the provision of entrepreneurship education to engineering students in Ireland.

Conclusions: Although the research finds examples of good-practice, the lack of educator competencies and organisational leadership needed to 'mainstream' entrepreneurship education within engineering programmes presents a significant challenge. Furthermore, its purpose is often misconstrued as being directly about creating graduate entrepreneurs and technology start-ups as opposed to entrepreneurial graduates. Over forty pedagogical tools were identified, yet the 'business-plan', a poor metaphor, remains the primary underpinning, making it difficult for engineering students see entrepreneurship in a wider contextual relevance that stimulates entrepreneurial behaviour and fosters mindsets.

McAfee, Marion and Reid, Stephen.
Institute of Technology Sligo

Challenges in Providing Practical Labs Online to Distance Learning Students

Abstract. Delivery of engineering courses on-line is a growing area of demand and one which has a key role to play in Ireland's economic development. The National Skills Strategy outlines the requirements to realise the government's vision of a new knowledge economy which can compete effectively in the global market place. This states the need to up-skill 170,000 individuals within the workforce to third level education by 2020. In this context, the ability to fit an on-line course around full-time work is of huge benefit to both students and their employers.

The Institute of Technology, Sligo is Ireland's leading online learning provider. Since 2001 the Institute has delivered "live" classes to distance learning students over the Internet on a range of courses from Ordinary Degree to Masters level. A major challenge faced in delivery of on-line engineering courses is the difficulty in linking theory with real world problems through practical application. IT Sligo are aiming to address this issue through a collaborative EU funded project, "Knowledge and Innovation Transfer in Engineering" (KITE). In this paper we describe the technology we use for facilitation of online practicals, and discuss the student and teacher experiences during the initial stage of the KITE Project.

McDermott, Rodney, Hegarty, Lynda and Strong, W. Alan.
University of Ulster & North West Regional College

Reflections on Trialling Two Teaching Strategies for Sustainability Management Education in an Undergraduate Engineering Module

Abstract. This paper focuses on the effectives of two teaching strategies on the topic of sustainability. The first strategy involved delivering a lecture using the TEAM EFFORT formula on the Construction Management module of the Civil Engineering programme at the University of Ulster, Jordanstown. This TEAM EFFORT formula is part of a teaching strategy used to deliver and evaluate the required multi-disciplinary approach to sustainability within the built environment. The TEAM EFFORT formula consists of: TE = Team Effort; AM = Appropriate Management; EF = Evaluation Framework; FO = Focused Outlook; and RT = Risk Translation.

The second strategy involved a TEAM EFFORT approach within the module again in the form of a management simulation assessment referred to as "The Game" which also focused on sustainability. Groups for The Game were from multi-disciplinary programmes within the School of the Built Environment including Civil Engineering, Building Services and Architectural Technologists. Over a 5-week period, the groups were given tasks to solve in terms of choosing the most appropriate answer to a given question from a choice of three possible answers. The tasks involved consideration of several factors including environmental, economic, social, safety and resources. The best performing group overall, in terms of selection and justification of their answer, was judged by a chosen industrialist.

Student assessment results for both strategies using this TEAM EFFORT approach showed that the students' awareness of the linkages across the four pillars of sustainability was improved. This highlights the effectiveness of these approaches to teaching and student learning.

Mitchell, Kyle, McCune, Keith, Yablonsky, Gregory, Gharabagi, Roobik and Ray, Ajay.
St Louis University & The University of Western Ontario

Teaching a Course "Technology and Energy Around You"

Abstract: An emerging introductory interdisciplinary course, in which students are introduced to the technology and energy needs they experience every day, is described.

The university community as a small city has been considered for study by students. The cooperation between various university constituents allows students direct access to the facilities to see some of their principles implemented into action facilitating the next step in the process, analyzing the resulting improvements. This cooperative effort creates a mutually beneficial situation where students gain access to the data and knowledge of the facilities personal; while the facilities personal gain access to the results, of the course studies, as possible directions for future action in sustainable efforts.

The emerging course focuses on introducing students to the technology and energy use of the university. This includes the space and resource needs of the community through the resource consumption modalities, particularly air conditioning, lighting, fresh air, potable water, non-potable water and safety requirements at all levels in the hierarchical university system. Physico-chemical and biological principles of utilities are explained from the very beginning.

Naher, Sumsun, McMorrow, Denise and Brabazon, Dermot.
Dublin City University

Employer and Student Perspectives on Skills for Engineers in the Twenty First Century and Beyond

Abstract. This research focused on skills identified among final year engineering students. It provided evidence of different levels of skills by students and identifies their greatest learning influences in these areas. The skills were self-assessed by students and covered seven areas designated by Engineers Ireland. Competency levels such as science, software, creativity, engineering practice, social and business, ethics, discipline specific were assessed. It also investigated the important role that work placements play in skills developed by students. Key skills sought by leading Engineering firms from graduates now and in the next five years were also researched in this paper. Employers were surveyed to determine and investigate skills needed from graduate engineers and how best to meet these challenges.

The emphasis on work placements and its impact on skills' development in engineering students such as business acumen and working effectively and efficiently in industry were highlighted.

Nobes, David, Stout, Curt and Ackerman, Mark.
University of Alberta

The Impact of Senior Design Project Workload on Student Performance

Abstract. Most, if not all, credible engineering programs have a senior design project as part of the curriculum. This capstone effort is intended to allow students to exercise four years of accumulated undergraduate education in the design or an object or a process. An increasing concern is the amount of work, time and stress undertaken by the students and the impact of this on their academic performance in this and other classes. The aim of this paper is to quantify the workload and examine the impact on student performance. The Senior Design Project (Mec E 460) in the Department of Mechanical Engineering at the University of Alberta aims to give the students a realistic experience in all aspects of industrial design. These includes not only the academics that the students have undertaken in their degree but also the other duties carried out by a designer which could include, defining the problem, interaction with the client and documenting and communicating the

solution. To achieve this, the program divides the students into teams of 4, provides them with their real problem from an industrial client and then steps them through a rigorous design process (the paper will include a detailed description of the program). Students are asked to track their work over the course of the design project in the form of a detailed Gantt chart. Based on these records, student teams have typically been reporting workloads of ~18 hours/person/week average of the 13 week semester and this may be as high as 26 hours/person/week. Data will be reported that compares the performance of these students to a second cohort of students who are not partaking in Mec E 460. The study indicates that while there is little evidence of a significant impact on student academic performance the perceived value of these types of design courses is large. Students' perception of the program from exit polls and student comments will also be discussed.

O Gallachoir, Brian.
University College Cork
Energy Engineering - A New Engineering Discipline or Simply a Pick and Mix?

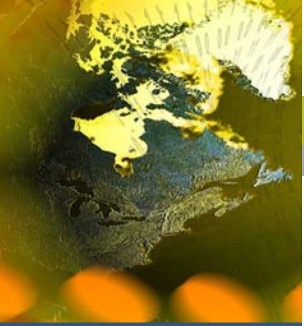
Abstract. The aim of this paper is to explore whether energy engineering is a new engineering discipline or a combination of existing disciplines. It is primarily a case study based on the experience in University College Cork (UCC), Ireland but also draws on available papers in the literature and other documented evidence from elsewhere. The paper discusses UCC's two programmes in energy engineering, a level 9 Masters Degree and level 8 Bachelor Degree. In the academic year 2009/2010, UCC attracted 290 applications for 25 places in its MEngSc Programme in Sustainable Energy. In addition, the minimum entry requirement for UCC's BE Programme in Energy Engineering was the highest for any undergraduate engineering programme in Ireland (510 points). This demonstrates the demand that exists for energy engineering programmes. The paper explores whether energy engineering is a new topic area in engineering, whether it is similar in this respect to building services engineering or environmental engineering. It also discusses whether in fact civil, mechanical and electrical engineering are the core disciplines or whether engineering itself is the only discipline. It concludes that energy engineering is certainly more than a pick and mix, that it is necessary and is here to stay.

O'Dwyer, Aidan.
Dublin Institute of Technology
Analysis of engineering students learning styles on Level 7, Level 8 and Level 9 programmes

Abstract. This contribution reports on research, carried out over three academic years, into the learning styles of engineering students, on a number of Level 7, Level 8 and Level 9 programmes at DIT, using the index of learning styles survey developed by Felder and Soloman (1991). The contribution explores the results obtained in detail, placing them particularly in the national context. The correlation between student performance and individual learning styles is examined. Knowledge of the strongly visual learning style of these cohorts of students may be used to improve the learning environment.

O'Dwyer, Aidan.
Dublin Institute of Technology
Experiences of Teaching, Learning and Assessment of Student Research Skills on a Level 9 Taught Programme in Engineering

Abstract. This contribution reports on the teaching, learning and assessment of a Research Methods module on a Level 9 taught programme in engineering at DIT. The module was run in the 2008-9 and 2009-10 academic years. The module is a generic one, whose aim is to facilitate students in developing a comprehensive proposal for their engineering research project. A team approach was taken to module instruction. Students were assessed (at different stages during the module) by evaluation of a written research proposal planner document, a reflective PowerPoint presentation and a final written research project proposal. The contribution reflects on the module experience, including



the lessons learned and the proposed further development of the module.

Olsen, Stig Irving.
Technical University of Denmark
A Strategy for Teaching Quantitative Sustainability Assessment

Abstract. Educating engineers to be active in sustainable development is by no means a trivial task and the challenge has been pursued by several universities and organisations around the world. At DTU MAN research and teaching is focused on engineering management tools. In the section for Quantitative Sustainability Assessment (QSA) the research and teaching is embedded in Life Cycle Assessment (LCA) and Life Cycle Management (LCM) tools. Our vision is that all engineers graduating from DTU are taught a basic knowledge about sustainability and the methods and tools to assess the sustainability of their decisions. Our strategy for the teaching address three target groups and follows two routes.
One route provides in-depth education• for students aiming to specialise in quantitative sustainability assessment. A variety of courses ranging from production level through company level to society level will be offered.
The second route aims to present concepts of sustainability and potential impacts of the specific technology field as well as methods and tools for specific domains, i.e. nano technology. It is targeted two groups of students at the different technological domains at DTU; those specifically working in innovation and technology development and engineers developing solutions based on existing technologies.
The DTU curricula will integrate sustainability assessment in introductory courses at bachelor level, whereas master level courses goes more in detail with the specific sustainability issues for that technology domain and introduces quantitative tools to assess sustainability. The proposed strategy embeds sustainability throughout the engineering curriculum.

Ožvoldová, Miroslava, Schauer, František and Beno, Miroslav
Trnava University & Tomas Bata University
Remote Free Fall Experiment for Dynamic Studies

Abstract. The internet remote experiment free fall of a permanent magnet in a glass tube with induction pick up coils for instantaneous position, velocity and acceleration measurements has been constructed (http://remotelab4.truni.sk). To transfer the hands-on experiment to the remote one, we lift the magnets in a glass tube by a magnetic vessel. The experiments was used with success for the study of the basis of mechanics and of the Faraday's Law.

Petruska, Jindrich.
Brno University of Technology
Introduction of Problem Based Learning to Mechanical Engineering Curricula

Abstract.
Aim:
In the paper we describe a running project funded by the European Social Fund, which is aimed at innovation of selected design-oriented curricula at the Faculty of Mechanical Engineering, Brno University of Technology, Czech Republic.

Content:
Although the technical learning has a long and successful tradition in Brno, new trends must be accepted to cope with the needs of modern industrial demands. From the communication with our industrial partners and graduates we registered serious drawbacks of contemporary educational system leading to low competency of our students in areas like:
- management ability
- adaptability and creativity

- communication, self-presentation, teamwork
- social, economical and juridical context of engineering activities.

To cope with this situation, an innovation of curricula in engineering areas like Applied computer science, Mechatronics, Engineering design, Robotics and Engineering mechanics and biomechanics was prepared. The key point of the innovation is the introduction of Problem Based Learning (PBL) into the above mentioned subjects. Main idea of PBL is shifting the educational process from the "'learning by hearing" to the "learning by doing" mode. Detailed presentation of this shift, problems with its introduction and first results will be described in the paper.

Conclusion:
First experience with the concept of Problem Based Learning shows a necessity of deep change of traditional role of the teacher as an instructing authority, student as a passive object and the education as a pre-fabricated process with a small proportion of individual creative contribution on both sides.

Pieskä, Timo.
Raahe School of Engineering & Business
Some Finnish Visions of Engineering Education

Abstract. The Finnish higher education system consists of two sectors: universities and universities of applied sciences. Both sectors have important engineering education.
The engineering education is today not very popular in Finland. That means problems in the future.

Some solutions:
A) The National Cooperation Group for Engineering Education (this group has members from the Ministry of Education, universities, unions and labor market) was assigned to produce a national strategy for engineering education in Finland. The Group submitted its interim report titled "Well-being from Technology through Cooperation" in mid-January 2008.
B) The mission of the Finnish engineering education is to benefit people and the environment through providing knowledge and skills, research and innovations for the society and business life. As part of the National Strategy Project for the Engineering Education it was seen necessary to find out what kind of learning objectives do the challenges associated with sustainable development impose on the Finnish engineering education and how have the units providing engineering education responded to these challenges. Therefore, a research study was conducted at the Finnish Association of Graduate Engineers TEK.
C) The Ministry of Education and all Finnish universities of applied sciences have the ENGIN –project. This project has three aims: attraction of engineering studies higher, studying time shorter and less interruptions of studies. The project consists three groups: a) group of structure development b) group of marketing c) group of teaching methods. The project has already organized some seminars and published two books of good learning practices.

Prabhu, Vittal and Yao, Tao.
Pennsylvania State University
Engineering Education in Service Systems

Abstract. The world's first industrial engineering academic program was established at Penn State by General Beaver, then Governor of Pennsylvania, in 1908. Since that time, the Department has graduated more than 7000 students. In 2005 the department faculty made major changes in the curriculum with the vision of educating the World Class Industrial Engineer. The major innovation in the new curriculum is specialization tracks in manufacturing systems, service systems, and information systems. The emphasis of this curriculum is educating students on the principles, tools and techniques of the industrial engineering profession which can be applied to these tracks. The revised curriculum builds a strong foundation for the development of a professionally competent and versatile

industrial engineer, able to function in a traditional manufacturing environment as well as in a much broader economy, including financial services, communication, information technology, transportation, health care, and consulting. Given the increasingly dominant role of services in the world economy, it is imperative that engineering curricula be systematically adapted to this significant shift. The aim of this paper is to present new courses developed to support the engineering services systems track along with some of the challenges faced in this effort. We will discuss in detail courses at the undergraduate and graduate level including Retail Services Engineering, Competitive and Sustainable Industrial Enterprises, Financial Engineering, Financial Services Engineering, and Information Technology for Industrial Engineering. We will conclude with a discussion on how these courses serve as a means for integrating the research efforts in the Center for Service Enterprise Engineering into the curriculum.

Pritchard, Colin.
The University of Edinburgh
Heat and Mass Transfer in the Long Rains: Doing Engineering under a Mango Tree

Abstract. Academic engineering exists primarily as a monoculture. In common with agricultural monocultures, it has a genetic (inherited) uniformity across international boundaries and climatic zones; it demands continuous and expensive inputs (of equipment, staff- and laboratory- time) and is highly susceptible to drought and common diseases (staff shortages, curriculum revision . .) A typical engineering degree is specialised, rarified, expensive – and often impractical and ill-suited to the demands made on it by societies struggling to take control of their own development.

In many practical situations, some basic engineering knowledge and understanding is all that is necessary to empower practitioners to take control of their own learning and investigations. But traditional classroom-based education doesn't imbue a "learning-by-doing" approach: passive- and rote-learning are the styles most usually adopted. Education "in the field" can give a major boost to students' self-motivation and self-learning. Once workers – from a wide variety of educational backgrounds, and none – have grasped some fundamental principles in their area of concern, they can take their own measurements, draw their own conclusions, and devise effective, locally-applicable engineering solutions to the practical problems they confront.

Examples are cited from the author's engagement with Knowledge Transfer Partnerships in Africa. In each case a short, intensive, practical on-plant course was devised which enabled factory workers, ranging from Form 4 leavers to degree qualified engineers, to take control of their own learning, make and interpret appropriate measurements on plant, and design measures to reduce energy costs, improve product quality and boost output and profits.

Purcell, Patrick, Dunnion, John and Loughran, Hilda.
University College Dublin
Experience of 'General Electives' in an Engineering Undergraduate Curriculum

Abstract. The incorporation of a number of non-core or general elective modules into engineering undergraduate curricula can be useful in developing broader graduate attributes. Elective modules enable students to deepen their knowledge in their chosen programme of study or expand their knowledge in other areas. General electives can be categorized as being either: (a) general interest (e.g. improving foreign language competences) or (b) generic/transferable skills (e.g. research skills). General electives can add significantly to the overall learning and development of students in a way that contributes positively to their disciplinary programme outcomes. The proposed paper will describe the evolution of general electives at UCD and examine the experience of the undergraduate Engineering Programme over the past five years with respect to such elective modules.

Queiroz, Ana.
ESEIG-Instituto Politécnico do Porto
Assessment of Bologna’s teaching approach in biomaterials sciences

Abstract. Student based learning (SBL) call forth new challenges to both students and teachers. A new approach to this methodology is being made in a Biomaterials unit of Biomedical Engineering will be presented.
Over the years, traditional lectures were replaced by controlled small assignments. Topics and respective references are given to students, that are encouraged to search for more information on scientific search engines and engineering specific libraries. A web based platform (moodle) has been an essential tool in this method since all the assignments and doubts may be shared on-line. The learning process is achieved by discussion and brainstorming in the classrooms.
Due to an existing evaluation system based on specific tasks and exams, one of the major drawbacks was the students’ difficulty to understand how, in this new methodology, evaluation would occur - even though they had specific assignments, 50% of the final grade was based in process learning. Difficulties have been overcome by a trial and error process that lead to a smoother learning process.
The approval rate of the students that underwent process learning was very high from the start, nevertheless adaptation problems have decreased and self learning and students autonomy is achieved at an earlier stage.
As assessment of the last three years of the implementation of this new teaching methodology will be presented. Pros and cons are evaluated and the methodology evolution is described.
This new approach has proven to be effective since students’ participation, doubts and enthusiasm for Biomaterials has increased. Nevertheless this is an evolving methodology, much like the biomaterials area itself.

Ramachandran, Sivakumar.
Institute of Art, Design & Technology
Engineering Education: Non-traditional Specialisms, and the New Economy

Abstract. Traditional technologically based industries significantly influenced higher education programmes of this kind, since industrialisation. A recent Irish appointment in the area of EU innovation and research indicates that non-traditional fields may play are more significant role in the ‘new economy’ of Ireland.

The demand for graduates and their employment patterns may change significantly. Sustainable employment opportunities may exist in different forms, such as short to medium term contractual opportunities. Potential applicants, with an enthusiasm to study technological based programmes, may consider non-traditional industries, in which to apply their potential expertise, and are of more interest to them. Even at this time, opportunities are growing. One example is the television industry, where Ireland has made commitments to provide a digital, high definition service by 2012.

This paper will review existing programmes that may be particularly well positioned for the ‘new economy’ and consider in more depth, the engineering degree programme in Digital Media Technology/Audio-Visual Media Technology at the Institute of Art, Design and Technology, Dun Laoghaire. These programmes, whilst primarily focused on the technical context, also provide a strong creative flavour. Past experience shows that this blend has enabled graduates to significantly improve their chances of employment.

Quantitative and qualitative analysis of graduate progression will be discussed, as well as the wider impact of graduates in shaping Ireland’s future prospects.

The conclusion of this paper will demonstrate the viability of degrees that offer new contexts in technical and engineering education, and satisfy the niches of industry for which demand is growing.

Ring, Denis and O' Leary, Raymond.
University College Cork & GlaxoSmithKline

The Role of Industry in Guiding the Pedagogy of Chemical Engineering Design

Abstract. Today's chemical engineering graduates work in a diverse range of industries many that are operating at the innovation, technological and business frontiers. Educating graduates with modern, relevant, design skills requires careful curriculum development and critically should combine input and feedback from industry.

Curriculum development is explored based on the Henley report (2006). This report identifies at least five broad areas of changes which it is felt will have a major impact on engineering:

1. Providing customer solutions, with the need to being focused on all of the customer's requirements and in doing whatever is necessary to solve them.
2. Increasing complexity of the technological domain leading to manufacturing incorporating numerous different technologies across different disciplines into a single product.
3. Globalization and recognition that even at the highest skill levels engineers are subject to international market competition.
4. Sustainability, emphasizing ecoefficiency, corporate social responsibility and operating these principles within the markets.
5. Innovation and creativity as forces which will differentiate products in an increasingly competitive marketplace.

A review of the current status of chemical engineering practice and education is presented alongside the drivers for educational change. Using questionnaires, opinions are compiled from students, lecturers and industry professionals evaluating the design teaching environment including the appropriate mix of defining and enabling skills.

The information and data collected provides a valuable insight into the development of chemical engineering design teaching. A future curriculum development scenario is presented for the enhanced teaching of plant & process design.

Ring, Denis and Oliveira, Jorge.
University College Cork

Incorporating a 5S Structured Approach to the Planning and Delivering of a Final Year Design Project

Abstract. The final year design project is a capstone, facilitating students in integrating all of their chemical engineering skills to delivering a specific body of work. In addition to the technical and scientific proficiency demanded in the development of the design solutions, students also need to address environmental and societal issues, provide marketing, business plans and analyse the economic feasibility of the investment. The ability for students to effectively cope with this multivariate task is key to a successful outcome.

The 5S management concept is originally associated with Kaizen a Japanese philosophy for achieving continuous improvement in production. A key concept of the 5S system is to empower those involved and thus embedding a real sense of project ownership. The value of students utilising such a structured approach to the formulation and development of their design project is explored. By placing their core project objective in the center and positioning the 5S engineering paradigms around this purpose will provide a methodology to continually reassess and improve the project as it progresses. In this case, however, the meaning of the "s" is different. Thus we see 5 key engineering concepts with the design goal paradigm:-

1. Sustainability The challenges faced are really opportunities
2. Safety: Embedding safety both in plant and product
3. Soft Skills: Innovation and leadership driving success
4. Simulation Facilitating technology transfer and process fitting.
5. Sectors Changing sectors of business operation for engineering

The incorporation of the 5S as a vehicle to promote the modern requirements of chemical

engineering in design is illustrated with the experience of the design project course of the chemical engineering degree at UCC.

Saha, Samir Kumar.
Jadavpur University
Curriculum Design of Mechanical Engineering in a Developing Country

Abstract. The curriculum and syllabi in Engineering Education is dynamic as it shifts with societal requirements as well as student inputs. The present paper deals with a study of the historical data of the changes in basic components of mechanical engineering curriculum in a developing country - the case study being that of Mechanical Engineering Department, Jadavpur University for last 50 years. Jadavpur University is presently ranked amongst the top 6 science and engineering institutes in India with respect to research ranking (based on Scopus data) or accreditation agency ranking (institution based). The study shows, that lack of local industrial input has been a predominant feature in changing the percentage of basic components in engineering curriculum and needs to be addressed even though technology is considered to be borderless now.

In the GATS regime, homogenization of engineering education is being attempted through Washington Accord, Bologna treaty etc. India is a signatory to the Washington Accord. Accordingly, AICTE, which is implementing this in India have formulated a curricular framework which includes 10-15% Basic Sciences, 15-17.5% Engineering Sciences, 10-15% Humanities social sciences and Management, Professional core 22.5-27.5%, Electives 19.5-25%, Seminar and Industrial Training 2.5-5% and Project 5-12.5%. However, author is of the opinion that even with cross-border movement of engineers, the national requirements should get priority in framing curriculum and syllabi of that country, which this work highlights with respect to one of top universities and research institutions of India, Jadavpur University. Such studies can give an insight into academic ranking and strength of the same department in various institutes.

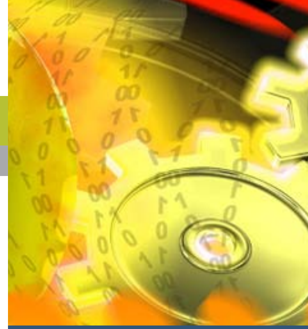
Strong, Alan and Hemphill, Lesley.
University of Ulster
Integrating Built Environment Studies through Sustainable Development Education

Abstract. The study sets out to crystallise the learning obtained from a pursuit to deliver ‘education for sustainable development’, in a higher education context and across eleven built environment professions, including the key engineering disciplines of civil, energy and environmental engineering.

This paper captures the key positive and negative elements, of a concerted ten-year drive to integrate sustainability thinking into the built environment disciplines at the University of Ulster. Funded initially by the Royal Academy of Engineers, this inter-disciplinary work required appointment of visiting professors, engagement with professional bodies, staff motivation and training, module design and development of appropriate pedagogy and assessment methods.

Evolution from Year 1 undergraduate sustainability awareness, through Year 2 sustainability application into technical modules, leading to final year sustainability integration across in-depth studies, design activity and research-focussed dissertations, gave a structure and coherence to the work, with the need for a focussed and broad-discipline staff team to maximise on the opportunity of success.

This integrative approach to ‘sustainability education being both complex and complicated’ was latterly applied at Masters levels. The challenge of sustainability thinking, in the context of international drivers, was embraced by students at all levels, with evidence from student, module and professional surveys highlighting the benefits of multi-disciplinary projects and encouragement of complimentary ownership by all professions.



Input and feedback from a Sustainability Visiting Panel and access to relevant case studies, allowed students and staff to engage holistic challenges, while positive reports from external Accrediting Bodies added weight to a mature sustainability education.

Strong, Alan, Woodside, Alan and McDermott, Rodney.
University of Ulster

Sustainability Principles Provide a Framework to Facilitate Integration of Design Processes

Abstract. Built environment professionals have been criticized for giving insignificant time to the design phase of major projects. Architects have been considered as the designers, leaving the roles of working out details and costs to Engineers and Surveyors.
The advent of 'Achieving Excellence in Construction' has led to more integrated approaches, an holistic project delivery through procurement, the appointment of joint venture multi-discipline consortia and a long-term approach by considering projects across conceptual, design, construction and operational stages.
This paper appraises the need for and delivery of an integrated approach by Engineers, avoiding a 'contract designer' profile and means for enabling and enhancing a holistic design process. Increased understanding of sustainability has allowed higher education students to identify with the connections across several themes such as energy, construction, waste, water, biodiversity and transport, so that a liner approach to design is replaced by integration and feedback evaluative mechanisms.
This sustainability-led design thinking has been developed with undergraduates at the University of Ulster, by encouraging students to adopt lateral thinking problem solving, learn from successes and failures, apply sustainability measuring systems in design decision-making, consider environmental, social and economic implications simultaneously and re-direct project solutions away form technical answers to the rationale for the project, inevitably involving radical alternatives.
The paper content is drawn from considerable design teaching experience across engineering disciplines, with input from industrialists, student reviews and professional body accreditation panels. It demonstrates the benefits of holistic design processes, systems thinking, and adopting a long-term approach to design to ensure that it is a fully integrated activity.

Tamtam, Abdalmonem, Gallagher, Fiona, Naher, Sumsun and Ghani Olabi, Abdul.
Dublin City University

Implementing English Medium Instruction (EMI) for Engineering Education in Arab World and Twenty First Century Challenges

Abstract. Developments of engineering education as well as modern technologies are considered most important requirements for twenty first century in globalised world. Recent research showed that there are significant knowledge gap in the required level of international communication for engineering graduates in Arab world countries. This is because of the medium of study is Arabic language in most places. To overcome this problem, it becomes and urgent necessary to implement English as a medium of study. In this paper an investigation was carried out from the available literature to find out the possible ways to implement English Medium Instruction (EMI) in Arab world engineering education. This paper also presents a comparison for some non native English countries outside Arab world, such as Netherlands and Indonesia which have already implemented EMI in engineering education. This study focuses on the problems faced by these non native, non Arab countries and explores the possibilities to put in practice the solutions suggested. The paper concludes that improving engineering education system in Arab countries is necessary by implementing EMI seeking the internationalisation system to achieve a world standard level of in both engineering and communication knowledge for engineering graduates.

Wade, Patricia and Sleator, Adele.
EirGrid plc
Educating EirGrid's Power System Engineers to Facilitate a Sustainable Future - a Partnership of Academia and Industry

Abstract. In this paper, we show how EirGrid works in partnership with Academic Institutions to develop engineering skills needed to facilitate a sustainable future.

Wang, Hui.
University of Saskatchewan
A New Graduate Course Teaching Chemical Engineering in use of Renewable Resources

Abstract. Fossil fuel resources such as natural gas, oil and coal will be used up in the future. Moreover, the current use of these resources has led to environmental risks such as global warming. Energy and materials based on fossil resources must be produced from other substitute resources in order to suppress the environmental footprint that has been posted and maintain and improve the current life styles of human being in the future. Renewable resources, or biomass, are one of these substitutes from which energy including fuels, and materials can be produced.

To bring students the awareness of utilizing renewable resources, a new graduate course, entitled Chemicals and Energy from Renewable Resources, has been implemented in the Department of Chemical Engineering, University of Saskatchewan lately. This course is divided into two parts. Part one deals with the basic processes such as gasification, pyrolysis, catalytic conversion and synthesis, separation unit operations in chemical and energy production from renewable resources. The content of this part includes reactor design, catalytic chemical engineering, and separation processes. Part two presents case studies of processes that produce energy and chemicals from biomass. Attentions are given to technology development, potential emission and pollution control and production economics.

Lecturing, class discussion, literature reviewing, doing project oriented assignments and student presentations are used. The case studies are closely combined with the research work of the students. The course has been welcome not only by the graduate students from this department but also those from other departments and colleges.

Willmot, Peter and Bamforth, Sarah.
Loughborough University
The use of Video Reports to Promote Active Engagement in Learning

Abstract. Twenty-first century students demand more than ever before: they expect courses to be fun to take part in and allow plenty of time for social interaction and revelry; they are increasingly driven by marks and reading appears to be a dying art. The expectation of today's paying customers is of 'teaching' not 'learning' and sadly, even a mild spell of disengagement can quickly lead to an unwelcome request for a course transfer.
Clearly, this does not sit well with the academic's need to convey large quantities of basic engineering science as the early building blocks of an engineering degree. Furthermore, today's intake is massively short of practical skills. As the world around us has changed, budding engineers no longer make their first associations with engineering at a young age by building Meccano models or repairing cars or bicycles; processes that can help to sow the seeds of an enquiring mind and enable students to understand better how the mechanical world works and how science is applied.
This paper describes how rising wastage rates prompted a department to tackle the real difficulties that school leavers have in adapting to undergraduate study head on. As part of a review of the first year curriculum in a demanding engineering degree programme, an innovative new problem-based module was introduced alongside traditional engineering

modules. The experiences were designed to improve study competences, to add interest and enjoyment and to address the gulf in attitude to learning that exists between staff and students. We exemplify here, a new student centered learning experience, designed to encourage teamwork and show how a novel video reporting approach that has proved both exciting for the students and efficient for staff.

Yablonsky, Gregory, Gleaves, John and Fushimi, Rebecca.
St Louis University, Washington University & Proteus Catalytic Solutions

Teaching Sustainability through Catalysis

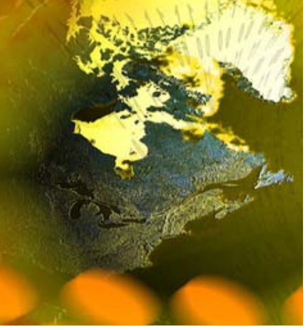
Abstract. Catalysis is the essential chemical phenomenon that underlies all living systems, and is key to creating sustainable processes and a greener environment (Armor 1999, Centi 2008). Catalysts accelerate chemical reactions, and efficiently channel energy into building complex molecular structures. Catalyst's ability to perform specific reactions with great precision through millions of cycles is the basis of sustainable processes. Thus the concepts of sustainability can be clearly illustrated using examples of natural and manmade catalytic processes.

Natural catalytic cycles, such as the photosynthetic production of carbohydrates, are made possible through enzymes. The efficient conversion of oil, gas, coal and biomass into fuels and chemicals is made possible by modern catalytic technology. About 90% of chemical manufacturing in the U.S. employs catalytic processes. Also, one of the most important environmental technologies is the catalytic converter, which removes NOx, CO and hydrocarbon pollutants from auto exhaust. In this discussion, the catalytic cycle is presented to facilitate the discussion of sustainability. Catalysis can be used to address some of the key problems facing the 21st century; in particular the production of fuels and chemicals in absence of petroleum is discussed here as an example.

On the cutting-edge of catalysis research is the Temporal Analysis of Products (TAP) reactor system. The TAP technique is a unique tool for capturing kinetic features (e.g. rates of transformation and energetic properties) of the fundamental molecular transformations occurring on catalytic surfaces. The TAP experiment can be remotely operated via an internet connection and data can be collected and analyzed within the time frame of a lecture. These experiments promote inquiry based learning where the outcome of one experiment will determine the conditions for setting up the next. This demonstration of the catalytic cycle in action will reinforce classroom learning of sustainable processes

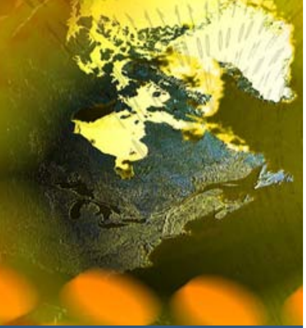
List of Attendees

1	Dr Basim Abu-Jdayil	United Arab Emirates University	United Arab Emirates
2	Ms Karen Adams	The University of Adelaide	Australia
3	Mr Ayodeji Adesina	Dublin City University	Republic of Ireland
4	Dr Esat Alpay	Imperial College London	England
5	Dr Sarim Al-Zubaidy	Heriot Watt University Dubai Campus	United Arab Emirates
6	Dr Bahawodin Baha	University of Brighton	England
7	Mr John Barrett	University College Cork	Republic of Ireland
8	Dr Gareth Bennett	Trinity College Dublin	Republic of Ireland
9	Mr Miroslav Beno	Constantine the Philosopher University	Slovak Republic
10	Ms Cintia Blaskovsky	Universidade do Estado do Pará	Brazil
11	Mr Kwame Boakye	Environmental Protection Agency-Training School	Ghana
12	Dr Brian Bowe	Dublin Institute of Technology	Republic of Ireland
13	Dr Dermot Brabazon	Dublin City University	Republic of Ireland
14	Prof Alan Bradley	Engineers Australia	Australia
15	Dr Andrea Brose	Hamburg University of Technology	Germany
16	Mr Donal Browne	University College Cork	Republic of Ireland
17	Dr Jitka Bruestlova	Brno University of Technology	Czech Republic
18	Dr Edmond Byrne	University College Cork	Republic of Ireland
19	Mr Richard Cadbury	London South Bank University	England
20	Ms Daniela Campos	ESEIG - Instituto Politécnico do Porto	Portugal
21	Mr Frank Carter	Institute of Technology Sligo	Republic of Ireland
22	Prof William Cleghorn	University of Toronto	Canada
23	Dr Jonathan Cole	Queen's University Belfast	Northern Ireland
24	Mr John Collins	Bord Gáis	Republic of Ireland
25	Dr Ruth Collins	Trinity College Dublin	Republic of Ireland
26	Mr Eddie Conlon	Dublin Institute of Technology	Republic of Ireland
27	Prof Thomas Cosgrove	University of Limerick	Republic of Ireland
28	Mr Donal Costello	University College Cork	Republic of Ireland
29	Dr Michael Creed	University College Cork	Republic of Ireland
30	Dr Kevin Cronin	University College Cork	Republic of Ireland
31	Mr James Curran	University College Cork	Republic of Ireland
32	Mr Sean Daly	University College Cork	Republic of Ireland
33	Dr Karl D. Dearn	The University of Birmingham	England
34	Ms Cheryl Desha	Griffith University Queensland	Australia
35	Dr Pavel Dobis	Brno University of Technology	Czech Republic
36	Mr Gavin Duffy	Dublin Institute of Technology	Republic of Ireland
37	Mr Noel Duffy	Cork Institute of Technology	Republic of Ireland
38	Mr Niall Dunphy	University College Cork	Republic of Ireland
39	Ms Louise Dunphy	Waterford Institute of Technology	Republic of Ireland
40	Dr Juliana Early	Queen's University Belfast	Northern Ireland
41	Mr Ben Ebenhack	University of Rochester	United States
42	Prof Anwar El-Hadi	Sudan Engineering Council	Sudan
43	Mr Lars Ericsson	Uppsala University	Sweden
44	Mr Sunday Faleye	University of South Africa	South Africa
45	Dr John Fitzpatrick	University College Cork	Republic of Ireland



46	Dr Colin Fitzpatrick	University of Limerick	Republic of Ireland
47	Prof Patrick Fitzpatrick	University College Cork	Republic of Ireland
48	Dr Raymond Flynn	Queen's University Belfast	Northern Ireland
49	Ms Aoife Foley	University College Cork	Republic of Ireland
50	Dr Raymond Foley	University College Cork	Republic of Ireland
51	Mr Marc Fry	Granta Design Ltd	England
52	Mr Paul Gallagher	University College Cork	Republic of Ireland
53	Mr Cathal Gallagher	Bord Gáis	Republic of Ireland
54	Mr Joshua Gbadebo	Hunan University	China
55	Dr Peter Gibson	University of Wollongong	Australia
56	Dr Jarmila Glassey	Newcastle University	England
57	Dr Robert Grepl	Brno University of Technology	Czech Republic
58	Mr Kevin Hanley	University College Cork	Republic of Ireland
59	Dr Robert Heinemann	The University of Manchester	England
60	Mr Paul Hermon	Queen's University Belfast	Northern Ireland
61	Dr Bettie Higgs	University College Cork	Republic of Ireland
62	Ms Michelle Hsieh	Granta Design Ltd	England
63	Dr Thomas Joyce	Newcastle University	England
64	Dr Plato Kapranos	The University of Sheffield	England
65	Mr Christian Kautz	Hamburg University of Technology	Germany
66	Mr Eoin Keegan	University College Cork	Republic of Ireland
67	Prof Alan Kelly	University College Cork	Republic of Ireland
68	Dr Patricia Kieran	University College Dublin	Republic of Ireland
69	Mr Chris Lambert	Lancaster University	England
70	Dr Paul Leahy	University College Cork	Republic of Ireland
71	Dr Ann Ledwith	University of Limerick	Republic of Ireland
72	Dr Ray Lynch	University of Limerick	Republic of Ireland
73	Mr Cormac MacMahon	Institute of Technology Blanchardstown	Republic of Ireland
74	Dr Pramod Mahajan	University College Cork	Republic of Ireland
75	Mr Daragh Mansfield	University College Cork	Republic of Ireland
76	Dr Marion McAfee	Institute of Technology Sligo	Republic of Ireland
77	Dr Kevin McCarthy	University College Cork	Republic of Ireland
78	Ms Marian McCarthy	University College Cork	Republic of Ireland
79	Mr Rodney PJ McDermott	University of Ulster	Northern Ireland
80	Mr Denis McGrath	Engineers Ireland	Republic of Ireland
81	Mr John McSweeney	University College Cork	Republic of Ireland
82	Ms Anne-Marie McSweeney	University College Cork	Republic of Ireland
83	Dr Thanos Megaritis	Brunel University	England
84	Mr Nicholas Kusi Mensah	Embry Riddle College of Management	Ghana
85	Mr Darren Mollaghan	University College Cork	Republic of Ireland
86	Mr John Mullins	Bord Gáis	Republic of Ireland
87	Dr Michael B. Murphy, President UCC	University College Cork	Republic of Ireland
88	Dr Tanya Mulcahy	University College Cork	Republic of Ireland
89	Dr Sumsun Naher	Dublin City University	Republic of Ireland

90	Prof Grace Neville	University College Cork	Republic of Ireland
91	Dr David Nobes	University of Alberta	Canada
92	Dr Brian Ó Gallachóir	University College Cork	Republic of Ireland
93	Dr Aoife O'Connell (Ahern)	University College Dublin	Republic of Ireland
94	Mr Neil O'Donnell	University College Cork	Republic of Ireland
95	Dr Aidan O'Dwyer	Dublin Institute of Technology	Republic of Ireland
96	Dr Jorge Oliveira	University College Cork	Republic of Ireland
97	Mr Gustavo Olivella	Granta Design Ltd	England
98	Mr Sikiru Olorunfunmi	UNILAG - University of Lagos	Nigeria
99	Dr Stig Irving Olsen	Technical University of Denmark, DTU	Denmark
100	Mr John O'Shea	Cork Institute of Technology	Republic of Ireland
101	Dr Dominic O'Sullivan	University College Cork	Republic of Ireland
102	Prof Jindrich Petruška	Brno University of Technology	Czech Republic
103	Dr Declan Phillips	University of Limerick	Republic of Ireland
104	Mr Timo Pieskä	Oulu University of Applied Sciences	Finland
105	Dr Emanuel Popovici	University College Cork	Republic of Ireland
106	Mr John Power	Engineers Ireland	Republic of Ireland
107	Prof Vittaldas Prabhu	Penn State University	United States
108	Dr Colin Pritchard	University of Edinburgh	Scotland
109	Dr Patrick Purcell	University College Dublin	Republic of Ireland
110	Mrs Ana Queiroz	ESEIG - Instituto Politécnico do Porto	Portugal
111	Mr Sivakumar Ramachandran	Institute of Art, Design & Technology	Republic of Ireland
112	Mr Stephen Reid	Institute of Technology Sligo	Republic of Ireland
113	Mr Frank Riedewald	University College Cork	Republic of Ireland
114	Mr Denis Ring	University College Cork	Republic of Ireland
115	Prof Samir Kumar Saha	Jadavpur University	India
116	Mr Brian Schafer	University College Cork	Republic of Ireland
117	Prof David Shallcross	The University of Melbourne	Australia
118	Mr Paul Sheridan	Engineers Ireland	Republic of Ireland
119	Mr Derek Sinnott	Waterford Institute of Technology	Republic of Ireland
120	Dr Maria Jose Sousa Gallagher	University College Cork	Republic of Ireland
121	Dr Victoria Stewart	Queen's University Belfast	Northern Ireland
122	Mr W Alan Strong	University of Ulster	Northern Ireland
123	Dr Magdalena Svanström	Chalmers University of Technology	Sweden
124	Mr Abdalmonem Tamtam	Dublin City University	Republic of Ireland
125	Prof Joseph Tatler	IMechE	United Kingdom
126	Mr Lukáš Tkác	Slovak University of Technology	Slovak Republic
127	Ms Niamh Tobin	University College Cork	Republic of Ireland
128	Mrs Patricia Wade	EirGrid plc	Republic of Ireland
129	Dr Hui Wang	University of Alberta	Canada
130	Mr Zack Washington	Environmental Protection Agency-Training School	Ghana
131	Dr Peter Willmot	Loughborough University	England
132	Prof David Wood	The University of Melbourne	Australia
133	Prof Grigoriy Yablonsky	Saint Louis University	United States
134	Mr Festus Yeboah	Politecnico di Torino	Italy
135	Mr Kevin Zaoui	Helion Hydrogen Power	France



NOTES

SOME GLOBAL COMPARISONS OF CHEMICAL ENGINEERING EDUCATION 21ST CENTURY STYLE

David Wood, Professorial Fellow, University of Melbourne
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Abstract: Chemical Engineering education has been formally recognised for over 100 years with people calling themselves chemical engineers in 1910 following the formation of the American Institute of Chemical Engineers. During this period university chemical engineering programs have drawn upon several paradigms which are well described by Hougen (1977) & Armstrong (2006).

In recent years we have seen strong suggestions for reform for both the curricula and the program structure e.g. Armstrong (MIT- Frontiers of Education project) (program), Bologna Accord (structure), Melbourne Model (program & structure). Each of these innovations have been proposed and in some cases implemented with significant opposition from traditionalists. An example of this is in the UK where there appears to be a great reluctance to even discuss the Bologna Accord let alone replace the traditional MEng program with the two stage Bologna program.

In China which is a Country which produces more chemical engineering graduates than the entire rest of the World only now are some universities adopting both structure and content of a standard equal to that in the UK and the USA. If the UK and the USA are leaders in content & structure what hope is there for the rest of us when Cussler (2005) refers to this content being 30 years out of date and Armstrong(2006) suggests 40 years out of date is valid?

1. INTRODUCTION

This paper discusses the typical global undergraduate chemical engineering programs in the 20th Century and the first decade of the 21st century. In the past 10 years there have been many criticisms of such programs and their lack of change with respect to the curricula.

Recent changes to program structure are described with particular emphasis on Australia (Melbourne dreamtime model), Europe (Bologna model), the UK (Integrated MEng), the USA (Frontiers) and China (Group of nine). In most cases the missed opportunity for curricula reform is emphasised and the question is asked if the World has the financial resources to offer a free or subsidised extended undergraduate education. Will students opt for lower cost non professional programs as an alternative form of chemical engineering education?

2. LOOKING BACK – 20th CENTURY

These programs are well described by a series of paradigms as presented by Hougen (1977), Armstrong (2006) and extended by Wood (2009).

The typical 1960s program emphasised material & energy balances, unit operations, fluid mechanics, heat transfer, kinetics and process design. Chemistry, physics and mathematics were well embedded into the program. Changes that occurred in the 1960s saw less emphasis on chemistry and the removal of physics together with a gradual introduction of transport phenomena (Bird et al), particle mechanics and reaction engineering (Levenspiel).

1905-1915 Industrial Chemistry	1915-1925 Unit operations	1925-1935 Material & Energy Balances
1935-1945 Thermo & Control	1945-1955 Kinetics Process Design	1955-1965 Trans. Phen React. Eng. I.T.
1965-1975 Proc. Eng. Biochem.	1975-1985 CAD Particles	1985-1995 More CAD
1995-2005 Prod. Design Res.	2005-2015 Biomolecular? Nano?	2015-2025 Molecular transformations Multiscale analysis Systems approach (Armstrong 2006)

Table 1: Chem. Eng. Paradigms

From the 1970s to the end of the century we witnessed a greater emphasis on biochemical engineering with a further loss of chemistry and a narrowing of the mathematics curriculum. Armstrong (2006) comments that over the last 30 to 40 years of the 20th century the Discipline of chemical engineering has undergone dramatic changes as have the research strengths of our universities. The industry that employs our chemical engineers has significantly broadened incorporating the pharmaceutical industry, environmental industry, communications industry, food industry and electronic industry with chemical engineers having knowledge and skills in materials finding themselves in an even broader range of employment. At the same time the metallurgical and mining schools in universities have contracted opening more opportunities for chemical engineers.
However many eminent chemical engineers, Cussler (2005), Armstrong (2006 and Davis (2009) comment that over the past 30 to 40 years including the transition into the 21st century the undergraduate curriculum worldwide has

remained without substantial change.

Armstrong (2006) suggests that the enormous growth in research in the universities which consumes a major fraction of the time of university staff has led to the neglect of the curricula content by faculty members in chemical engineering programs. In 2001 Australia hosted its first World Congress of Chemical Engineering and almost 2,000 of us heard Lord May (then chief scientist of the UK) (2001) tell us that *“the scope of chemical engineering is very wide creating extra difficulties for constructors of curricula. It is essential for the future to have a basic grounding in molecular biology, genomics, ecology, environmental science, biomedicine, plant science as well as the traditional science and maths.”*

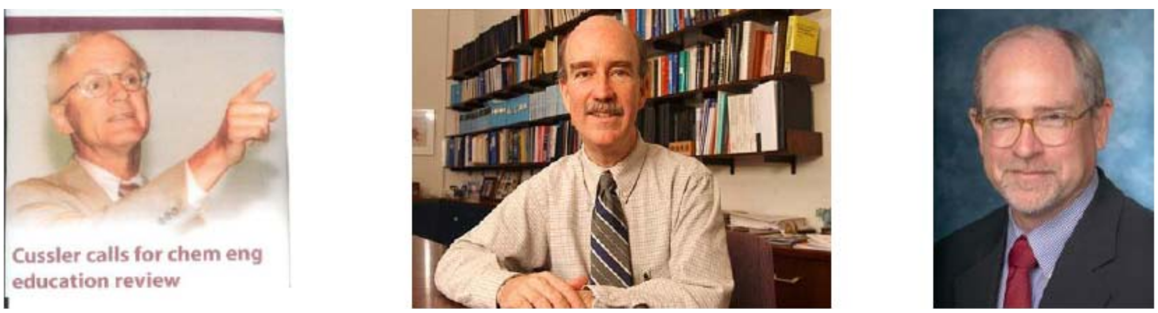

Figure 1: Professors Cussler, Armstrong & Davis

He also advised us to *“aim for a broad rigorous coverage of basic ideas principles, complimented by a few, carefully selected, applications in depth.”* In the same Congress John Perkins (2001) formally of Imperial College and Manchester University advised us *“to consider carefully the evolution of chemical engineering education over the past 100 years and that worldwide there were over 1000 departments of chemical engineering producing 50,000 graduates each year”*

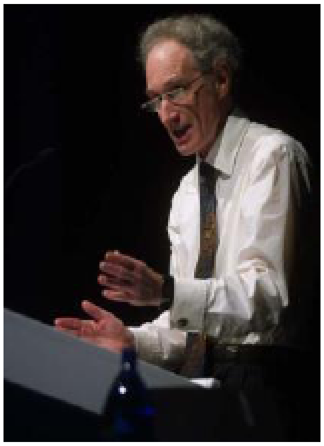 

Figure 2: 6th World Congress – Lord May & Professor Perkins

3. LOOKING FORWARD – 21st CENTURY

3.1 Challenges

At the 2001 World Congress we were challenged by Professor Bob Brown (then at MIT) (2001) who asked *"How will chemical engineering education embrace molecular, synthetic & mechanistic aspects of engineering, particularly as we address the new biological industries?"*

Further challenges for our constructors of curricula came in "Beyond the Molecular Frontier" (2003) which encourages chemists and chemical engineers to focus on understanding molecular chemistry and molecular scale transformations. As Armstrong (2006) notes, the modern curricula must produce graduates who can meet the 13 challenges proposed in the Beyond the Molecular Frontiers Report. Typical of the challenges is: *"Understand and control how molecules react - over all time scales and the full range of molecular size."* In terms of sustainability we see: *"Understand the complex chemistry of the earth, including land, sea, atmosphere and biosphere, so we can maintain its liveability."* Other challenges for our curricula are informed in the IChemE Roadmap for chemical engineers (2007) and the RSC Roadmap for chemists

(2009)

3.2 How are the challenges being met by our educators?

The warnings of Cussler, Armstrong and Davis were very clearly made in the first decade of the 21st Century clearly implying that little has been done to prepare our graduates for meeting the challenges of the century. We can examine these using examples from different global regions.

In general a chemical engineering undergraduate program consists of a specific structure within which lies the curricula. The traditional structure of the 20th century was a 4 year degree program including fundamental science and engineering in the early years leading to focussed chemical engineering topics in later years finishing with capstone projects for design and research.

The knowledge explosion towards the end of the century has forced educators to look at extending the program structure (Melbourne, Bologna) or to restructure the curricula to fit within the existing structure (USA – Frontiers). Many of our universities especially those in Asia, Africa, the Middle East and the Indian sub continent have simply ignored the challenges for the future and neither structure nor curricula have changed.

3.2.1 Australia-The Melbourne Model

Figure 3: University of Melbourne

The University of Melbourne pioneered a complete reform of undergraduate education throughout the whole University (including Engineering with some resistance). The model which is also being considered by some other Australian universities is a two stage model over 5 years enabling students to have a far broader education as well as specialising in specific fields of study e.g. chemical engineering. The first stage involves study for a 3 year Bachelor degree in one of 6 fields- Arts, Science, Economics, Environments, Performing Arts and Biomedicine. At least 25% of the program must be taken up with courses from disciplines other than the selected core discipline thus producing a more “rounded” chemical engineer with strong attributes for employment.

The second stage of the model is normally of 2 years duration for the Masters degree with specialisation in chemical engineering. It is certainly an undergraduate degree in terms of content although there have been suggestions that because it is a second degree it is more like a conventional Masters postgraduate program which is incorrect. Melbourne University claims that it has a considerable impact on the ratio of graduate students to undergraduates!

The great advantage of the Melbourne model is not only the opportunity to include breadth in the program but it provides time to include so called “drill down depth” in selected courses. Adoption of the model has provided the University of Melbourne with an excellent opportunity to reform the curricula to meet the challenges of Beyond the Molecular Frontier and the roadmaps. An inspection of the Melbourne program suggests that this opportunity has been missed.

Year 1 - semester 7	**Year 1 - semester 8**
Advanced Heat & Mass Transport Processes	Advanced Thermo. & Reactor Engineering
Biomolecular Process Principles	Bionanoengineering
Particle Mechanics & Processing	Chemical Engineering Elective
Chemical Engineering Management	Chemical Engineering Elective

Year 2 - Semester 9	Year 2 – Semester 10
Process Equipment Design	Chemical Engineering Design Project
Process Engineering	Chemical Engineering Design Project
Chemical Engineering Elective	Chemical Engineering Research Project
Chemical Engineering elective	Chemical Engineering Research Project

Table. 2: Sample of the Master of Engineering program at the University of Melbourne

With the exception of Tissue Engineering the electives are "conventional" chemical engineering courses. The University of Melbourne has raised the entry requirements to the Masters cycle to well beyond the normal pass level for the bachelor's degree. An inspection of the curricula suggests that this is unnecessary and it may be driven by financial considerations. Many outstanding graduates of former years and senior engineers in the Australian profession would have been unable to gain entry to professional chemical engineering education had such constraints existed in the past.

3.2.2 Bologna Model

The Bologna model is similar to the Melbourne model in terms of duration although in general there is a requirement for the Bachelor's component to consist of 7 semesters each of 30 ECTS (European credit transfer system) including a period of work placement. The Masters component whilst normally of 4 semesters (120 ECTS) has a provision for duration of 3 semesters (90 ECTS) with an absolute minimum of 60 ECTS, presumably to satisfy the British universities.

To date there is insufficient information available to assess if the programs have embraced significant curricula reform. The changes that have been made to German university programs to comply with the Bologna model suggest that within the Bachelor component there is some breadth material but only approximately 11% of the ECTS. This model makes provision at the Bachelor level for the inclusion of a design project and a thesis which is a significant improvement on past practice.

Using the German Chemical Engineering programs as an example the Masters component provides two alternatives:-

- More research oriented program
- More applications oriented program

In the research oriented program the fields of study are 50 to 85 ECTS devoted to an extension of mathematical, scientific and engineering subjects. If this means an extension of the subjects specified in the bachelor program it includes mechanics, thermodynamics, fluid mechanics, electrical engineering etc.! Also separation science, solids handling, reaction engineering and manufacture of apparatus and machinery! The remaining credits are for breadth subjects and a thesis. The thesis provides scope for tackling the challenges but this does not look like curricula for the 21st Century. Not much evidence of reform!

3.2.3 USA

When Armstrong (2006) commenced the Frontiers in undergraduate chemical engineering education project at MIT a number of other chemical engineering departments (53) and Faculty members (150) in the USA joined the Frontiers workshops. The workshops made an important observation namely: *"if the curricula is thought of as large blocks e.g. thermodynamics, transport phenomena, kinetics, mass & heat transfer etc. then change will be difficult or impossible."* The reason for this is that current programs are already full of content and there is no room or no will to include new content. Hence the Frontiers workshops started from a *"clean slate"* and designed a new program to meet future challenges. It was quickly realised that in addition to the enabling sciences there is a core set of organising chemical engineering principles viz:

- Molecular transformations – including chemical & biological & physical as well as chemical structural changes.

- Multiscale analysis – from sub molecular to super macroscopic scales for physical, chemical & biological systems.
- A systems approach.

Furthermore it was deemed essential to recognise that chemical engineering includes both product and process design. In considering the new concepts it was recognised that the "*old core material*" does not integrate molecular concepts; it covers only macro to continuum systems and it is tied to large scale chemical processes.

The Frontiers programs remain of 4 years duration and it is likely that providing accreditation issues do not impede progress that many of the programs in the USA will move towards those developed in the Frontiers workshops and major curricula reform will have been achieved.

3.2.4 UK

Engineering programs in the UK underwent a major structural reform following the Finniston report in 1980. This led to the introduction of the 4 year MEng degree program (5 years in Scotland) and this does not fit well with the Bologna cycles. In the UK it is considered that the Bologna use of the ECTS leads to a "time served" approach which is contrary to the learning outcomes approach of the UK MEng. The traditional MEng degree is now referred to as "an integrated 4 year Masters degree" and it is clearly not a 3+2 structure. The 240ECTS equivalent of a UK degree is less than the limit of 270ECTS prescribed under the Bologna requirements.

A chartered engineer under the Bologna treaty is defined as one having an accredited bachelor's degree with honours in engineering or technology plus an appropriate Master's degree accredited or approved by a professional engineering institution **or** appropriate further learning to Master's level **or** an accredited integrated MEng degree.

The professional institutions in the UK have generally assumed that the integrated MEng degree is Bologna compatible and whilst this may be true by definition the intense programs in the UK provide little opportunity for genuine curriculum reform to meet the challenges of Beyond the Molecular Frontier.

With respect to academic quality there is no doubt that the top chemical engineering programs in the UK e.g. Imperial College & Manchester, are outstanding by global academic standards, however, there is a need for curricula reform.

3.2.5 China

Chemical Engineering education in China is likely to have a major impact on the rest of the World during the 2nd and 3rd decades of the 21st Century. The number of chemical engineering graduates produced each year from Chinese universities is extremely large and larger than the rest of the countries of the World put together. (Fig.6).

There are almost 300 chemical engineering departments in China (~150 in the USA). If all of the departments are ignored except the very top group of 9, these departments produce the same number of chemical engineering graduates as the whole of the USA. Each chemical engineering department in the Group of 9 is outstanding by World standards and the student/ staff ratios are much lower than in other countries. The top rated chemical engineering school in China for undergraduate programs is Tianjin University and its chemical engineering program was accredited by the IChemE to the Integrated MEng level in 2008. Nevertheless the curricula is very traditional 20th Century style and overloaded with basic sciences and weak in design.

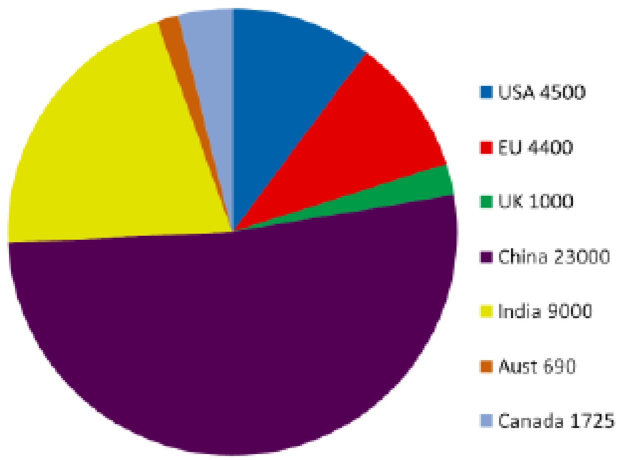

Figure 4: Chem. Eng. Graduates per year

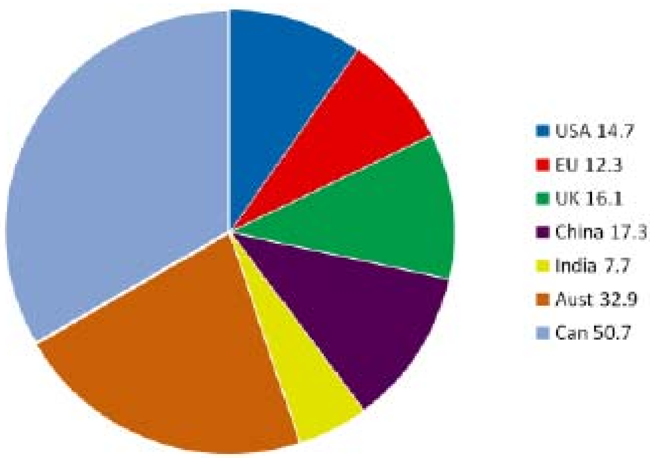

Figure 5: Grads. per m of population

China recognises the need for major curricula reform, however, there is no professional chemical engineering institution in China which is capable of encouraging such reform. With the recognition for curricula reform and the desire to achieve and maintain high level western accreditation it is certain that China will invest far more money per capita in chemical engineering education than any other country. This is likely to drive curricula reform to a level where the challenges of Beyond the Molecular Frontier are not only recognised but met. The strength of research in Chinese universities is such that there is no shortage of an intellectual driving force to significantly reform and improve the undergraduate programs during the second decade of the 21st Century.

4. FINANCIAL CONSIDERATIONS

There are major financial considerations that must be addressed as the new programs progress further. In many countries students pay relatively small tuition fees for their university education. In the UK there are long term repayable student loans, however, with the impact of the Global financial crisis (GFC), major Government debt and the recent budget it is likely that student fees will become prohibitive thereby slowing the growth in students enrolling in expensive professional chemical engineering degrees.

In Europe where a virtually free university education has been the norm the GFC and the Euro Zone meltdown will also have a major impact. The cost of the 2 cycle, 5 year undergraduate program will be well beyond the ability of many students and their families to finance and termination after the first 3 year component may be an attractive option.

In China where fees are low, students are already complaining of the impact of the fees. To date there is no evidence of a downturn in student demand. If China was to adopt a Bologna type 2 cycle undergraduate degree program this could prove to be well beyond the normal family budget or preferred form of expenditure.

In the USA where high fees are the norm the major impact will be the effect of the GFC, however, as the economy grows, with families used to borrowing to provide university fees, financial issues should not be a major restraint to achieving professional chemical engineering undergraduate education.

In Australia the move to the Melbourne Model at the University of Melbourne has been praised by many employers and the scheme's architects as a great forward development in undergraduate education! This may be so and certainly it brings many opportunities for curricula reform even if these opportunities have not been taken. Nevertheless the annual cost of educating an engineering undergraduate is approximately A$31,000. In its move from a 4 year to a 5 year program the cost imposition to students and their families is enormous with the cost of the degree rising by at least A$31,000 plus the extra living costs! Government loans through repayable fee help scholarships are in general restricted to 3 year or 4 year programs although Melbourne has been able to offer a limited number of scholarships to its Master's students. Whilst Australia was only lightly affected by the GFC there remains significant Government debt and with a possible change of Government this year it is likely that there will be a reduction in recurrent University funding for the years ahead. This may lead to a move away from expensive degree programs such as Engineering.

5. CONCLUDING REMARKS

The move for program structural reform in university chemical engineering education has dominated the far more important requirement for curricula reform. The Melbourne model, Bologna model and the UK integrated MEng programs provide many opportunities but there is no evidence of in depth curricula reform.

It appears that the Melbourne model offers the best structure for major curricula reform if the financial constraints permit. The Frontiers programs of the USA are leading the way in curricula reform.

Worldwide there have been significant structural changes to chemical engineering programs, however, in general the opportunity for concurrent curricula reform has not been taken. New programs have significantly increased the cost of higher education for chemical engineering students and this poses a threat to the number of well qualified chemical engineering graduates entering the profession in the future.

The professors who lead our chemical engineering schools at the World's universities with a few exceptions in the USA, have let the profession down in not meeting the challenges for chemical engineering education reform and hence the future contribution of the profession to the global problems and challenges that society faces is diminished.

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ENGINEERING EDUCATION FOR SUSTAINABLE DEVELOPMENT: A REVIEW OF INTERNATIONAL PROGRESS

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Abstract:

Since the late 1980s there have been increasing calls around the world for embedding sustainability content throughout engineering curricula, particularly over the past decade. However in general there has been little by way of strategic or systematic integration within programs offered by higher education institutions (HEIs). Responding to a growing awareness towards the issues surrounding sustainability, a number of professional engineering institutions (PEIs) internationally have placed increasing emphasis on policies and initiatives relating to the role of engineering in addressing 21st Century challenges. This has resulted in some consideration towards integrating sustainable development into engineering curricula as envisaged by accreditation guidelines. This paper provides a global overview of such accreditation developments, highlighting emerging sustainability competencies (or 'graduate attributes') and places these in the context of relevant PEI declarations, initiatives, policies, codes of ethics and guideline publications. The paper concludes by calling for urgent action by PEIs, including strategic accreditation initiatives that promote timely curriculum renewal towards EESD.

Keywords; engineering education for sustainable development, sustainability, accreditation, curriculum renewal, competencies, graduate attributes.

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1. ENGINEERING EDUCATION FOR SUSTAINABLE DEVELOPMENT

1.1. Introduction –conceptions of terms

While the terms ‘sustainable development’ (SD) and ‘sustainability’ are often used synonymously as encompassing a cause and effect relationship, neither of these terms themselves have universally agreed meaning. In 1987, the Brundtland Commission’s report (WCED, 1987) defined sustainable development as *‘development that meets the needs of the present without compromising the ability of future generations to meet their own needs’*. This definition has attained universal traction and is seen by many who recognize the current unsustainable nature of society as a means of achieving sustainability. For example, the Royal Academy of Engineering published guiding principles on engineering for sustainable development in 2005, to address the problem that, *‘We are exceeding the capacity of the planet to provide many of the resources we use and to accommodate our emissions, while many of the planet’s inhabitants cannot meet even their most basic needs’* (RAE, 2005).

Others argue that sustainable development, even by the Brundtland definition, can be (and often is) interpreted more liberally, in such a way that entrenches a ‘business as usual’ paradigm, and thus can actually prevent the realization of a sustainable future. For example MIT chemical engineering professor emeritus John Ehrenfeld (2008, pp.5;21) suggests that; *‘sustainable development is not actually a vision of the future. It is merely a modification of the current process of economic development … All* [its ‘programmatic prescriptions like eco-efficiency’] *have some potential to mitigate or slow down the unsustainable trajectory of the globe, but all are only quick fixes.’* Ehrenfeld (2008, p.7) thus encapsulates the problem with SD as he sees it: *‘Almost everything being done in the name of sustainable development addresses and attempts to reduce unsustainability. But reducing unsustainability, although critical, does not and will not create sustainability.’*

Ehrenfeld defines sustainability, as *‘the possibility that human and other life will flourish on the planet forever’* (Ehrenfeld, 2008, p.6). This concept is analogous to the concept of backcasting (the antithesis of forecasting), whereby some future (sustainable) state is envisioned, and then one works backwards to develop a current platform which has the fundamental potential to accommodate the future envisioned state. This will inevitably involve nudging at cultural norms – that is, helping alter observed behavioural patterns over time and space, through clever and innovative design. Backcasting thus represents an envisioned future, which Stasinopoulos *et al* describe as representing *‘the desired outcome rather than the transition … so as to be applicable at many levels, to many fields and industries. A general vision will encourage a flexible system that can adopt to unforeseen technological and political disturbances.’* (Stasinopoulos *et al*., 2008, p. 88).

With such perceptions in mind, the Brundtland definition has underpinned most discourse since its publication, spawning widely recognized terms such as ‘education for sustainable development’ (ESD) and ‘engineering education for sustainable development’ (EESD). Indeed, the United Nations (UN) has been instrumental in developing these concepts and it has named the decade 2005-2014 the ‘UN Decade of Education for Sustainable Development’ (DESD), led by UNESCO (UNESCO, 2005). The UN defines ESD as education that encourages *‘changes in behaviour that will create a more sustainable future in terms of environmental integrity, economic viability, and a just society for present and future generations’* (UN, 2002); increasing the capacity of individuals, groups or organisations to contribute to sustainable development, through content and skills acquisition.

Within this context, the term 'sustainable engineering' has a variety of meanings. For example, Dowling's definition of sustainable engineering includes a clear eco-efficiency focus: '*practices that promote environmental, social and economic sustainability through greater resource efficiency, reduced pollution and consideration of the wider social impacts of new technologies, processes and practices*' (Dowling et al, 2010, p. 333). A potential issue with approaches that are characterized by improving efficiencies, is the phenomenon known as the 'rebound effect', whereby gains in efficiency can be negated by subsequent increases in consumption levels without the necessary corresponding change in mindset (Clift, 2006). Technological improvements in the absence of conceptual change might thus be characterized as putting the cart before the horse, with similar consequences. Sustainable engineering literature often includes commentary regarding the importance of technological eco-efficiency particularly in the short term, accompanied by longer term cultural and behavioral change.

Despite the rapid growth in discussion about the need for engineering education to incorporate sustainability knowledge and skills, an internet search of definitions did not provide any documented definitions for the widely used term 'engineering education for sustainable development' (EESD); nor any definitive lists of desired competencies, graduate attributes or learning outcomes. However, according to the World Federation of Engineering Organisations (WFEO, 2002) (WFEO represents 15 million engineers from more than 90 nations), EESD means education that encourages engineers to play, *'an important role in planning and building projects that preserve natural resources, are cost-efficient and support human and natural environments'*. On the basis of this statement, EESD can be considered to be an all-encompassing term, including the teaching of technical, social and economic aspects of development. For the purposes of clarity, the term EESD will henceforth be used through the remainder of this paper in such a broader, all-encompassing sense, whereby it envisages the achievement of sustainability as a function of both paradigmatic and technological change.

1.2. Calls for a new conceptualization of engineering

Professional organisations around the world have been declaring an urgent need to keep up with the pace of change and forming collaborations to make progress, in particular since the early 1990s. For example, in 1992, together with the International Union of Technical Associations and Organizations (UATI) and the International Federation of Consultant Engineers (FIDIC), WFEO created the World Engineering Partnership for Sustainable Development (WEPSD) (Carroll, 1992), which has since been active in promoting a new vision of engineering as one which befits 21st Century challenges (Ridley and Ir. Lee Yee-Chong, 2002). Many have hypothesized that 21st Century engineering will have little to do with creating fossil fuel-based products and services (Cortese, 2007; RAE, 2007; Borri, 2008). Australian engineer and 2009 WFEO president and former president of Engineers Australia Barry Grear questions the type of world that engineers will presently inhabit (Grear, 2008);

> *'What aspirational role will engineers play in that radically transformed world?'… An ever-increasing global population that continues to shift to urban areas will require widespread adoption of sustainability. Demands for energy, drinking water, clean air, safe waste disposal, and transportation will drive environmental protection [alongside] infrastructure development'.*

However, it has been pointed out that these challenges will require a new approach to engineering practice, one characterised by a broader more expansive self conceptualisation. In addressing this situation, in 2009 the UK Engineering Council concluded in their report *Guidance on Sustainability for the Engineering Profession*;

> *'A purely environmental approach is insufficient, and increasingly engineers are required to take a wider perspective including goals such as poverty alleviation, social justice and local and global connections. The leadership and influencing role of engineers in achieving sustainability should not be under-estimated. Increasingly this will be as part of multi-disciplinary teams that include non-engineers, and through work that crosses national boundaries.'* (ECUK, 2009)

2. SIGNS OF PROGRESS INTERNATIONALLY

There has however been substantial progress made internationally over the past decade or so in relation to EESD. A review of such progress as presented in the literature by individual authors or groups is outlined in Appendix 1. Addtionally, there have been a number of key international surveys on the state of EESD. These are summarized in Appendix 2, and the latest two, which relate to the state of EESD in the USA and Europe will be reviewed.

As part of the US Center for Sustainable Engineering study, Allen and others at the University of Texas at Austin, Carnegie Mellon University and Arizona State University (Allen et al, 2008) have produced a comprehensive review of accredited engineering programs that incorporate sustainability concepts across the USA. While just 20% of programs responded, 80% of these report *'teaching either sustainable engineering focused courses or integrating sustainable engineering material into existing courses'*. The main findings of the study were that courses concentrate primarily on smaller systems, particularly those limited to the firm (gate-to-gate or design for environment) or product (cradle to grave or environmental life cycle analysis), while less than half of the courses address larger systems that examine relationships between different firms or industrial sectors (industrial ecology) or between industrial and non-industrial sectors (cultural and social dimensions). The authors also found that sustainability engineering material was taught to classes of predominantly upper division undergraduate and graduate students, and while discrete sustainable engineering courses seemed to be the most common approach, material is also incorporated throughout programs. The study reports the following among its key findings:

> *'The engineering education community is now at a critical juncture. To date, there has been a significant level of "grass-roots" activities but little structure or organization. The next step will be for engineering accreditation bodies to think critically about what should or should not be included in a curriculum into which sustainable engineering has been incorporated. The path forward will require the evolution of a set of community standards.'*

The authors also report:

> *'We believe a long-term goal of 21st century engineering education is to enable practicing engineers to incorporate tenets of sustainability into all phases of their*

> *practice, so that "sustainable engineering" eventually equates with "good engineering".'*

One aspect of the study which makes comparison of practice difficult was its subjective nature; *'the questionnaire [provided] did not provide a comprehensive definition of either "sustainability" or "sustainable engineering," which reflects the state of the art, but necessarily increases the subjectivity inherent in these results.'*

This is also the case in a biennial European based study by the EESD Observatory, which aims to report on *'the extent that sustainability is embedded in European engineering education'* (EESD Observatory, 2006; 2009). It has published rankings based on both self selection with the aim of measuring progress against the Declaration of Barcelona (EESD, 2004). Embedding SD within the curriculum was just one of five criteria used to rank institutions. The results here were not very enlightening as all institutions were either given a (self selecting) score for embedding of either 100% or 0%; neither of which is very credible outcome for what is in reality an elusive entity to measure! Two other criteria are *'the number of courses and specializations on SD offered at undergraduate level'* and *'postgraduate program on SD divided into number of Master Programs offered by the university, number of credits (ECTS) and when the program started'* relate to programs. The report does not offer much by way of analysis apart from commenting that more universities took part compared with a similar exercise two years previously (EESD Observatory, 2006) and that more received higher grades.

In conclusion, the literature suggests an *ad hoc* and highly variable approach to such curriculum renewal and it is concluded that there has not been a large-scale transition to producing engineering graduates with the knowledge and skills to meet the changing needs of the profession over the coming one to two decades in particular. Moreover, while engineering education has undergone periods of curriculum renewal to embed professionalism, ethics, and health and safety, the profession has not had to make a significant shift in the way it fundamentally teaches students across all disciplines since the first engineering professionals emerged following the Industrial Revolution (Jorgensen, 2007).

3. DECLARATIONS, ACTION PLANS, POLICIES AND OTHER INITIATIVES

3.1. Key declarations and action plans

Over the last two decades there have been growing global calls for change in higher education towards ESD from a variety of international bodies. A number of resulting declarations and action plans which have been explicit about the need for transitioning to ESD as soon as possible are highlighted in Appendix 3.

These have formed the broader context for calls for EESD more widely. The 1997 report of the Joint Conference on Engineering Education and Training for Sustainable Development in Paris called for sustainability to be *"integrated into engineering education, at all levels from foundation courses to ongoing projects and research"* and for engineering organisations to "*adopt accreditation policies that require the integration of sustainability in engineering teaching"* (JCEETSD, 1997). This was followed by the 2004 Declaration of Barcelona (EESD, 2004) which outlined how universities and engineering educators need to change;

> *'to prepare future professionals who should be able to use their expertise not only in a scientific or technological context, but equally for broader social, political and*

environmental needs. This is not simply a matter of adding another layer to the technical aspects of education, but rather addressing the whole educational process in a more holistic way, by considering how the student will interact with others in his or her professional life, directly or indirectly. Engineering has responded to the needs of society and without a doubt, today's society requires a new kind of engineers.'

The Declaration of Barcelona (EESD, 2004) also made a radical call on institutions and universities to redefine their missions *'so that they are adapted to new requirements in which sustainability is a leading concern'* and for universities to '*redirect the teaching-learning process in order to become real change agents who are capable of making significant contributions by creating a new model for society.'* Additionally, the World Engineers' Convention in 2004 (UNESCO, 2004) also published a declaration on engineering and a sustainable future.

From a qualitative review of mainstream international and regional engineering conference programs spanning the last 5 years (including the Australasian Association of Engineering Education annual conferences, the Global Colloquia on Engineering Education, and the International Conference on Engineering Education) it is clear that major engineering forums are now featuring engineering education for sustainable development as a theme for submission and presentation. Topics covered in submitted papers include issues affecting the ability of engineering education to be changed, including for example organisational issues, resourcing issues, personality issues, funding issues, timeframe issues, and content issues. Papers discussing overstretched resources and declining student intake into environmental disciplines are common features within the programs. Some of the papers appearing in such conferences document success, including case studies and flagship courses (first year, and masters level) but these efforts are rarely documented as part of a longer term strategic plan for curriculum renewal.

Recently there has also been a shift in some global 'mainstream' engineering education conferences, with regard to the themes and requests for papers. For example, the 2008 *7th Global Colloquium on Engineering Education* (GCEE) theme was 'Excellence and Growth in Engineering Education in Resource Constrained Environments', with a research track focused on 'Inferring and Designing Engineering Education Practice from Research and Societal Context: To what extent should engineering educators collaborate globally to re-engineer their programs?' (ASEE, 2008). However, although the 2008 International Conference on Engineering Education theme was 'New Challenges in Engineering Education and Research in the 21st Century' including invited topics on environmental challenges and the role of Engineering Education in Sustainable Development, only two out of more than 235 presentations, and three out of more than 65 posters explicitly addressed either of these topics, and these were case studies (ICEER, 2008).

3.2. Policy statements

Alongside calls for greater emphasis on EESD internationally, PEIs have also been envisaging a increased role for sustainability and sustainable development among the engineering community, as evidenced in policy statements and other initiatives as shown in Table 4.

Table 1. Examples of strengthening professional requirements for EESD

Date	Key Documents Outlining Professional Requirement
1990	FIDIC introduced environmental policies including guidelines on the obligations of the consulting engineer with respect to their projects and clients 'Engineers should provide leadership in achieving sustainable development'. (FDIC, 2004) FIDIC, the United Nations Environment Program (UNEP), and the International Chamber of Commerce (ICC) developed training programs for their members and for industry to provide guidance on how to describe and analyse environmental issues as well as setting up environmental management systems. (UNEP, undated)
1994	Engineers Australia developed a policy on sustainability in 1994 which required that 'members, in their practice of engineering, shall act in a manner that accelerates achievement of sustainability' (Carew and Mitchell, 2006).
1992 – 1996	World Engineering Partnership for Sustainable Development - WFEO, FIDIC and the UATI - formed a collaboration to lay the groundwork for the many programs in support of sustainable development that are being pursued by WFEO, FIDIC and other international organisations through their members and committees.
1997	Eighteen national and international institutions representing the chemical engineering profession globally signed the London Communiqué which pledged *'to make the world a better place for future generations'* (Batterham, 2003).
1997	Joint paper entitled 'Role and Contributions of the Scientific and Technological Community to Sustainable Development', produced by the International Council for Science (ICSU), WFEO, Third World Academy of Sciences (TWAS), the InterAcademy Panel (IAP), and the International Social Science Council (ISSC), (Joint Paper, 2001) following the 1996 World Congress of Engineering Educators and Industry Leaders, organized by UNESCO, UNIDO, WFEO and UATI which devoted considerable attention to education and sustainable development concerns. The World Federation of Engineering Organisations also produced 'The Engineer's Response to Sustainable Development' (WFEO, 2007).
2001	WFEO Model Code of Ethics, which states that, *'Engineers whose recommendations are overruled or ignored on issues of safety, health, welfare, or sustainable development shall inform their contractor or employer of the possible consequences'*. (WFEO, 2009)
2001	6th World Congress on Chemical Engineering: twenty chemical engineering institutions signed the Melbourne Communiqué (2001), a one page document committing each of them to work towards a shared global vision based on sustainable development.
2004	The United States National Academy of Engineering formulated its vision of the Engineer of 2020 (NAE, 2004). This report outlines a number of aspirational goals where it sees the profession taking a more central normative role in society, including facilitating design *'through a solid grounding in the humanities, social sciences, and economics'*, rapidly embracing new fields of endeavour *'including those that require openness to interdisciplinary efforts with nonengineering disciplines such as science, social science, and business'* and taking a lead in the public domain by seeking to influence public policy positively. Critically, the report calls for engineers to be informed leaders in sustainable development and notes that this *'should begin in our educational institutions and be founded in the basic tenets of the engineering profession and its actions'*. It suggests that engineering curricula be reconstituted *'to prepare today's engineers for the careers of the future, with due recognition of the rapid pace of change in the world and its intrinsic lack of predictability'*.

<table>
<tr><th>Date</th><th>Key Documents Outlining Professional Requirement</th></tr>
<tr><td>2005</td><td>The Royal Academy of Engineering (London) published a set of twelve ‘Guiding Principles’ for engineering for sustainable development (RAE, 2005), in a document which also provided examples and applications for curriculum implementation. The RAE has also sponsored a visiting professors scheme in the UK from 1998 ‘to embed the topic of engineering for sustainable development into engineering course and not to create a separate subject’ (RAE, 2005). The 12 Principles are:
1. Look beyond your own locality and the immediate future
2. Innovate and be creative
3. Seek a balanced solution
4. Seek engagement from all stakeholders
5. Make sure you know the needs and wants
6. Plan and manage effectively
7. Give sustainability the benefit of any doubt
8. If polluters must pollute… then they must pay as well
9. Adopt a holistic,‘cradle-to-grave’ approach
10. Do things right, having decided on the right thing to do
11. Beware cost reductions that masquerade as value engineering
12. Practice what you preach.</td></tr>
<tr><td>2006</td><td>International Federation of Engineering Education Societies (IFEES) - a network of 35 engineering organisations including WFEO and FIDIC - formed to establish effective engineering education processes of high quality around the world, to assure a global supply of well-prepared engineering graduates. According to Founder and President Professor Claudio Borri, ‘In a few words, the key-question posed by the 21st century global economy to engineering educators and stake-holders is this: How can education in science and technology help to reduce poverty, boost socio-economic development, and take the right decisions for sustainable and environmental compatible development?’ (Borri, 2008)</td></tr>
<tr><td>2006</td><td>The Canadian Council of Professional Engineers published a ‘National Guideline on Environment and Sustainability’ in 2006 (CCPE, 2006) which outlined nine tenets that professional engineers should adhere to. It states that engineers:
1. Should develop and maintain a reasonable level of understanding, awareness, and a system of monitoring environmental and sustainability issues related to their field of expertise.
2. Should use appropriate expertise of specialists in areas where the professional engineer’s knowledge alone is not adequate to address environmental and sustainability issues.
3. Should apply professional and responsible judgment in their environmental and sustainability considerations.
4. Should ensure that environmental planning and management is integrated into all their activities which are likely to have any adverse effects.
5. Should include the costs of environmental protection among the essential factors used for evaluating the economic viability of projects for which they are responsible.
6. Should recognize the value of environmental efficiency and sustainability, consider full life-cycle assessment to determine the benefits and costs of additional environmental stewardship, and endeavour to implement efficient, sustainable solutions.
7. Should engage and solicit input from stakeholders in an open manner, and strive to respond to environmental concerns in a timely fashion.
8. Should comply with regulatory requirements and endeavor to exceed or better them by striving toward the application of best available, cost-effective technologies and</td></tr>
</table>

Date	Key Documents Outlining Professional Requirement
	procedures. Should disclose information necessary to protect public safety to appropriate authorities. 9. Should actively work with others to improve environmental understanding and sustainability practices.
2007	The Institution of Chemical Engineers, a signatory body at London and Melbourne, followed through as part of these commitments by drawing up *'A Roadmap for 21st Century Chemical Engineering'* (IChemE, 2007). In practice, this is a type of strategic plan for chemical engineering largely based on moving towards a sustainable future. Each of its six themes, which include 'sustainability and sustainable chemical technology' and 'health, safety, environment and public perception of risk', incorporates strong sustainability threads. Progress on the roadmap was published in 2008 (IChemE, 2008).
2007	Engineers Australia launched a formal sustainability charter in 2007 (Engineers Australia, 2007). This takes a broad view, purposely placing a particular emphasis on the social sphere, an area where engineering has traditionally been weakest (Segalàs et al., 2008). The charter proposes the institution's belief that *'sustainable development should be at the heart of mainstream policy and administration in all areas of human endeavour'*. It also notes that achieving this will not be easy and *'requires a fundamental change in the way that resources are used and in the way that social decisions are made'*. Here an engineering institution is recognising the normative and multi-disciplinary role that engineers can and must play in helping achieve a sustainable global society while also inviting its members to take a larger global view of their roles and perhaps take the lead in finding solutions to relevant issues.
2009	Engineering Council UK (ECUK, 2009) has set out six guidance principles on sustainability for the engineering profession which, it suggests respective professional engineering institutions may wish to use in developing guidance for their members. These are: – Contribute to building a sustainable society, present and future – Apply professional and responsible judgement and take a leadership role – Do more than just comply with legislation and codes – Use resources efficiently and effectively – Seeking multiple views to solve sustainability challenges – Manage risk to minimise adverse impact to people or the environment The third principle provides an implicit admission that the professional codes do not go far enough while the fifth one offers a humble acknowledgement that engineers do not, and cannot have all the answers to the problems arising from our unsustainable societal construct, nor can they alone turn things around. Indeed, they also suggest that engineers should use their influence to help drive future legislation and codes. ECUK clearly envisages a broad, ambitious and integrative role for the 21st Century engineer and suggests; *'the leadership and influencing role of engineers in achieving sustainability should not be under-estimated. Increasingly this will be as part of multi-disciplinary teams that include non-engineers, and through work that crosses national boundaries.'*

Table 4 demonstrates that there has been a general trend from general to specific alongside a progressive heightening of the bar in terms of commitments and expectations over time. This is in line with broader societal context which has seen a progressively stronger emphasis on sustainability and sustainable development as discussed earlier.

4. CODES OF ETHICS

Most PEIs either have a code of ethics or professional conduct which their members are required to adhere to. As an umbrella body, the World Federation of Engineering Organisations has published a model code of ethics (WFEO, 2001). Most national and international professional engineering institutions follw a code of ethics which reads along similar lines. A selection of codes of ethics (Enginers Australia, 2000; IPENZ, 2005; Engineers Ireland, 2009) and the references within them which relate to sustainable development/sustainability are highlighted in Appendix 4.

Among the published codes it is clear that sustainable development/sustainability is envisaged as an area of ethical responsibility for practicing professional engineers. However, rather than the codes of ethics setting sustainability/sustainable development as the very *context* of engineering practice, whereby as Allen at al (2008) envisage *'sustainable engineering ..equates with good engineering',* that is good engineering in both practical and ethical terms, these concepts instead appear more by way of add-on statements that may accompany terms such as 'social', 'environmental', 'safety' and 'health and safety'. This is perhaps suggestive of a larger problem with incremental rather than holistic changes to code of ethics documentation as issues emerge in the profession, though it may also be a function of the relatively recent emphasis on this issue and one which will be addressed among future versions of codes of ethics, as they naturally evolve to reflect evolving PEI policies. At any rate, PEIs such as the UK'S Engineering Council appear to acknowledge this issue when they issue among their six guidance principles on sustainability for the engineering profession that engineers should *'do more than just comply with legislation and codes.'* (ECUK, 2009).

In more general terms, a common theme among these code of ethics statements is also a narrow focus on the individual agent, to the detriment of a broader context, such as a responsibility to act an agent of cultural or societal change. This emphasis on the individual agent has implications in the curriculum as it leads to teaching of ethics based on contrived scenarios which overestimate the influence of individuals within an organisational structure and fails to represent the social, organisational, complexities of real engineering practice (Bucciarelli, 2008). This, Bucciarelli argues, is a minimalist approach which drains inspiration from the profession by failing to meet the engineering student's natural *'positive inclinations to do good'.* Conlon (2008) picks up on this theme and argues that *'A focus on the wider social context is also required if engineers are to contribute to creating a sustainable society.'* In practical terms, Conlon (2010) suggests at this Symposium a broader ethical framework from the field of sociology which engineers could adopt which would envisage both micro and macro issues; for example, acknowledging the responsibility of engineers not just to design components or processes safely, but of at least equal importance, to also consider a culture of safety stemming from *'the organisational culture, the regulatory regime and public policy'*. Such an approach, Conlon argues, could take *'adequate account of the commitment and power of engineers to pursue such goals as safety, sustainability and the enhancement of human welfare.'*

5. ACCREDITATION GUIDELINES

The accreditation process is a powerful instrument in directing the education of engineers and over the longer term, the capacity of the engineering profession.The Royal Academy of Engineering highlight the importance of accreditation as an agent for evolution and change in their report on educating engineers for the 21st Century (RAE, 2007) where they observe that *"the accreditation process for university engineering courses should be proactive in driving the development and updating of course content, rather than being a passive auditing exercise"*.

Accreditation guidelines have evolved as relatively organic entities that continually change to reflect national legislative requirements and strategic policy direction in addition to the ethos of the accrediting PEIs. However, the pace at which accreditation guidelines incorporate various declarations, initiatives, communiqués, charters and policies, appear to be often beset with a significant time lag. This adds to the subsequent considerable time lag between issuing guidelines and widespread implementation throughout programmes, and again between programme implementation and widespread professional practice as highlighted by Desha *et al* (2009). Within this context and given the recent emergence of sustainability related imperatives for engineering education, a significant challenge exists to incorporate such aspects into accreditation requirements in a timely manner. To assist with the ISEE2010 workshop deliberations in this regard, Appendix 5 provides an overview of current accreditation guidelines with respect to sustainability for a number of PEIs globally.

Most of the PEIs considered here come under the mutual recognition umbrella of the International Engineering Alliance's Washington Accord, which seeks (not yet mandatory) adherence to a common set of rules, procedures and performance guidelines (IEA, 2010), as part of the Alliance's expectations for membership. For example, the IEA includes in its guidelines for member institutions a 'graduate profile exemplar'. The strongest and most explicit recommendation with respect to sustainability/sustainable development is that graduates should '*understand the impact of engineering solutions in a societal context and demonstrate knowledge of, and need for, sustainable development*' (IEA, 2007).

However, there is in fact a broad range in outcome requirements among PEIs internationally. This ranges from the most detailed and explicit descriptors based on a learning outcomes approach in countries such as Australia, the UK, Canada, Germany and Ireland, to a more generalised learning outcomes approach which simply provides a number of headings (without further explanatory detail) in countries such as the USA, Japan, Taiwan, etc. There are also accreditation process which appear not to be based on programme learning outcomes at all (e.g. India), to places which appear to have had no accreditation procedure in place at all historically (e.g. China). It seems ironic that areas with the least stringent accreditation requirement produce the highest numbers of engineers. For example, China graduates far more engineers annually than any country (with 600,000 college and university graduates in 2005), while India produces in the region of 350,000-500,000 per annum. By comparison, the USA graduates about 70,000 engineers annually, while Europe produces 100,000 (including 12,000 from the UK) and Australia produces about 6,000 per annum (Desha & Hargroves, 2010).

The accreditation requirements relating to sustainability for institutions in the following countries/international entities are related in Appendix 5, including Ireland, UK, Europe, Germany, France, USA, Canada, India, China, Australia, New Zealand, Japan, Taiwan, and Hong Kong. Specifically, the following terms were sought to identify those accreditation criteria related to EESD:

- sustainability/sustainable development;
- environmental or social issues;
- ethical issues, but only in the context of either of the above;

- multi-disciplinarity; and
- complexity or complex systems, and related (open ended/‘wicked’) problems.

6. CONCLUSIONS AND FUTURE CONSIDERATIONS

This paper began with a discussion of the terminology used surrounding sustainability, sustainable development followed by a review of the literature available on EESD, policies and initiatives of PEIs as well as codes of ethics and accreditation guidelines.

However, the extent of literature on a number of important related topics is lacking. For example, there is an absence of rigorous study on the relative role of the engineering profession in addressing broader issues relating to (un)sustainability such as climate change and water, food and energy supply and demand, or on the importance of interdisciplinary and multidisciplinary action between engineers and others. There are also few academic studies focused on whether shifting expectations necessitate a shift in the knowledge and skills needed to practice as a professional engineer. Furthermore, there appear to be no studies comparing success in student recruitment or departmental viability for those departments who incorporate EESD against those who don’t. There is also a lack of data assessing relationships between career success for engineers with and without sustainability related capabilities. In such a rapidly emerging field these ‘gaps’ in academic literature are problematic, but do not prevent further exploration of the topic.

In conclusion, despite the growth in literature on the need for EESD, there has not yet been a rigorous global review of this discipline undertaken by any single organisation or collaboration. Conference themes and journal topics have tended to focus on issues affecting the ability of engineering education to be changed (i.e. organisational, resourcing, funding, timeframe and content issues), rather than the extent to which the curriculum has changed. Within EESD literature, the most prolific papers have been on the topic of single champions or teams discussing individual initiatives in the subject area of EESD. Some papers have documented the success of strategically embedding case studies and flagship courses (predominantly in first year, and at post-graduate level), and few papers have discussed methods to integrate sustainability theory, understanding and application across programs and across disciplines.

Within this context, it is hoped that the ISEE2010 Delegate Workshop, in conjunction with Professional Institutions’ Forum at ISEE2010 can play a significant role in exploring the issues involved, and perhaps move the discussion forward. As an ISEE2010 keynote speaker David Wood in his opening plenary address to the World Congress of Chemical Engineering in Montreal in 2009 (Wood, 2009), exhorted:

> *‘If our role is to address the challenges of the 21st Century (e.g. ‘The Roadmap’), it is essential that our undergraduate programs must be reformed – NOT MORE OF THE SAME.’*

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APPENDIX 1 LITERATURE REPORTING ON EESD INTERNATIONALLY

There is a growing volume of engineering education literature on the topic of what EESD should comprise within the engineering curriculum, including content and pedagogical practices. Over the last 10 years discourse has moved from attempting to understand the term 'sustainability' as it relates to environmental education, social science, higher education (for example authors such as Sauvé,[1] Fien,[2] Leal,[3] Sterling,[4] Corcoran and Wals,[5] Parkin *et al*[6], Cortese,[7] Blewitt and Cullingford,[8]and Dawe *et al*[9]), and the engineering profession (for example Jansen,[10] Mulder,[11,12] Ferrer-Balas *et al*[13], Holmberg *et al*[14]), to attempting to understand what knowledge and skills graduate engineers should be equipped with (for example Carroll,[15] Cortese,[16] Crofton,[17] Ashford,[18] Azapagic *et al,*[19,20] McKeown *et al,*[21] Pritchard *et al*[22] and Allenby *et al*[23]), how EESD should be taught with regard to pedagogical practices (for example Timpson *et al*[24] on tips for integration, Newman and Fernandez[25] who discuss institutionalising such curriculum renewal, Steinemann[26] and Lehmann *et al,*[27] who write about problem based learning, and Crawley *et al*[28] who discussed the need for sustainable development to form a framework within which engineering education needs to be rethought), and the larger education agenda (for example Rowe who discusses policy direction,[29] Stephens and Graham[30] who discuss research needs, Steinfeld and Takashi[31] who discuss the challenge of trans-disciplinarity, and Holdsworth *et al*[32] who discuss the need for professional development for ESD).

Internationally, a number of professional organisations have also undertaken reviews on the topic, such as the 2005 American National Academy of Engineering (NAE) report on educating the engineer of 2020,[33] the 2006 UNESCO workshop on Engineering Education for Sustainable Development,[34] the 2007 UK Royal Academy of Engineering (RAE) report on educating engineers for the 21st Century,[35] the Higher Education funding Council for England (HEFCE) *Strategic Review of Sustainable Development in Higher Education in England,*[36] and the Chinese Academy of Engineering.[37] There are also numerous authors writing about local experiences in trying to embed EESD within their own universities around the world, as highlighted in Table A1.

Table A1. Examples of papers on EESD initiatives

Country/ Region	Example author and institution details
Europe	Kamp[38] and Mulder[39] in Netherland's Delft University; Lundqvist *et al*[40] in Sweden's Chalmers University; Fenner *et al*[41] in the UK's Cambridge University; Humprhies-Smith[42] in the UK's Bournemouth University; Lozano[43] in Wales' Cardiff University; Fletcher *et al*[44] in England's Aston University; Ferrer-Balas *et al*[45] in Spain's UPC.
North America	Allenby *et al*[46] national overview; Epstein *et al*[47] in the Massachusetts Institute of Technology; Mihelcic *et al*[48] in Michigan Technical University;
South America	Lozano-Garcia *et al*[49] in ITESM Monterrey; Wright *et al*[50] writing about the collaboration between Michigan University and Chile's University of Concepción
Asia	Onuki and Takashi[51] in Japan's University of Tokyo; Uwasu *et al*[52] in Japan's Osaka University; Kuangdi[53] in a Chinese national overview.
Africa	Olorunfemi and Dahunsi[54] in Lagos State Polytechnic and the University of Ibadan, Nigeria; Ramjeawon[55] in the University of Mauritius.
Australia	Davis and Savage[56] in Queensland University of Technology, Goh[57] in the University of Southern Queensland, Bryce *et al*[58] in the University of Technology Sydney, Mitchell[59] in the University of Sydney; Carew and Therese[60] in the University of Wollongong; Koth and Woodward[61] in the University of South Australia; Daniell and Maier[62] in the University of Adelaide; Carew and Lindsay[63] in the University of Tasmania and Curtin University;[64] Mann and Smith in computing engineering.[65]

Within the literature highlighted in Table A1, there are many references to ensuring that engineers have a good understanding of: global systems and ecosystem principles; economic, social and environmental risks; impacts and opportunities associated with their engineering solutions; and knowledge and skills in sustainable development related tools and technologies. Further to this, authors such as Pérez-Foguet *et al*[66] also discuss the need to incorporate developing country issues into engineering studies, and authors such as Boyle,[67] Steinfeld and Takashi,[68] Kumazawa *et al*,[69] and Mihelcic *et al*[70] present an emerging field of 'Sustainability Science' as a way to describe what should be taught in EESD, which incorporates the notion of transdisciplinarity, and which integrates industrial, social, and environmental processes in a global context.[71]

Given the broad spectrum of conceptualizations regarding sustainability, sustainable development and EESD, there is unsurprisingly a very broad range of conceptualization of what embedding such content into the engineering curriculum might mean and indeed how this is applied in practice. With this in mind, we now consider the extent to which progress has been made, before proceeding to examine the type of accreditation and other requirements being established by PEIs.

APPENDIX 2 SUMMARY OF KEY SURVEYS ON THE STATE OF EESD

Year	Survey	Brief Description
1998	World Engineering Partnership for Sustainable development	Questionnaire circulated to national members of WFEO to provide an improved benchmark. Conclusion: No strong or consistent approach to environment and sustainable development in engineering education. On a country average, not much more than 10 per cent of time in 10 per cent of courses is devoted to these aspects.[72]
2000-2002	University of Surrey (UK) and University of Melbourne (Australia)	Survey of a sample of international engineering students on their level of knowledge and understanding of sustainable development; the first of its type.[73] Conclusion: (21 respondents from 40 invitees) The level of sustainable development knowledge is not satisfactory, and significant knowledge gaps exist within the curriculum.[74]
2002	Royal Melbourne Institute of Technology	Twenty-one Australian universities invited to participate in a survey on the status of ESD in these institutions. Conclusion: (from a quarter of invitees) Few universities are engaged in such education for a wide range of their students. In some universities more students of particular disciplines are gaining exposure. However, there are clear barriers to the introduction and expansion of sustainability education.[75]
2006	Chalmers University of Technology, Delft Technical University, Technical University of Catalonia, Alliance for Global Sustainability	The Observatory assessed the status of EESD in European Higher Education, benchmarking 51 European Universities (survey), against examples from outside Europe. Conclusion: To-date there is no European University that shows sufficient progress in EESD to be considered an inspiration.[76]
2007	Forum for the Future's Engineers of the 21st Century Programme	499 young engineers (online) who had graduated between 1997 and 2005 surveyed regarding sustainability literacy.[77] Conclusion: 40 percent perceived their university lecturers had inadequate knowledge of sustainability. 30 percent perceived their lecturers had a positive to passionate attitude about ESD.
2007	National Framework for Energy Efficiency[78]	National survey on the state of engineering education in Australia, within the sub-topic of energy efficiency education. Conclusion: The state of education for EE in Australian engineering education is currently highly variable and ad hoc across universities and engineering disciplines. Key issues for educators included perceived course overload, and lack of time for professional development or to prepare new content.
2007-2008	US Center for Sustainable Engineering	Benchmarking survey on the extent of sustainable engineering education within 1,368 engineering departments (or the equivalent), with just over one fifth of the invited 364 American universities and colleges participating.[79] Conclusion: The engineering education community is now at a critical juncture. To-date, there has been a significant level of 'grass-roots' activities but little structure or organisation. The next step will be for engineering accreditation bodies to think critically about what should or should not be included.[80]
2008	Chalmers University of Technology, Delft Technical University, UPC, Alliance for Global Sustainability.	Second survey by *The Observatory*[81] initiative. Of the 57 universities participating in the 2008 survey, most had not participated in the 2006 survey, making it difficult to directly compare results of the reports. Conclusion: A growing number of institutions from European countries are actively engaged in sustainability activities.

APPENDIX 3. EXAMPLES OF DECLARATIONS PROMOTING ESD

Date	Declaration	Brief Description
1990	Talloires Declaration	The Talloires Declaration is a ten-point action plan for colleges and universities committed to promoting education for sustainability and environmental literacy in teaching, research, operations and outreach at colleges and universities.[82] The role of the university is defined as, *'Universities educate most of the people who develop and manage society's institutions. For this reason, universities bear profound responsibilities to increase the awareness, knowledge, technologies, and tools to create an environmentally sustainable future'*.[83]
1992	Agenda 21	The need for education to play a key role in addressing the challenge of sustainable development was articulated within the global community two years later at the Rio Earth Summit in 1992, with its action plan *Agenda 21*[84] calling for education. This was acknowledged in a range of national planning documentation around the world.[85]
1997	Thessaloniki Declaration	This declaration was made unanimously by 83 countries, relating to education and public awareness for sustainability [86]
1998	World Declaration	UNESCO World Conference on Higher Education produced the *World Declaration on Higher Education in the Twenty-First Century: Vision and Action,* which stated that, *'Without adequate higher education and research institutions providing a critical mass of skilled and educated people, no country can ensure genuine endogenous and sustainable development'*.[87]
2000	Earth Charter	The United *Nations Earth Charter* released in 2000, also provided a general statement of ethics and values for a sustainable future.[88]
2001	Lüneburg Declaration	This declaration was adopted by the GHESP partners (IAU, ULSF, Copernicus Campus and Unesco), on the occasion of the International COPERNICUS Conference, titled 'Higher Education for Sustainability Towards the World Summit on Sustainable Development (Rio+10)'.[89]
2002	Ubuntu Declaration	At the 2002 World Summit on Sustainable Development, this declaration was created for all levels of education, focusing on the need for education and science and technology for sustainable development.[90]
2002	Ubuntu Declaration	At the 2002 World Summit on Sustainable Development, this declaration was created for all levels of education, focusing on the need for education and science and technology for sustainable development.[91]

APPENDIX 4 EXTRACTS FROM SELECTED PEI CODES OF ETHICS

The World Federation of Engineering Organizations has published a model code of ethics (WFEO, 2001). The most explicit parts on the issue of sustainability contained within it include the following excerpts:

'Issues regarding the environment and sustainable development know no geographical boundaries. The engineers and citizens of all nations should know and respect the environmental ethic. …

II. PRACTICE PROVISION ETHICS.

Professional engineers shall [among other requirements]:

- *hold paramount the safety, health and welfare of the public and the protection of both the natural and the built environment in accordance with the Principles of Sustainable Development;*
- *be aware of and ensure that clients and employers are made aware of societal and environmental consequences of actions or projects and endeavor to interpret engineering issues to the public in an objective and truthful manner; …*

III. ENVIRONMENTAL ENGINEERING ETHICS
Engineers, as they develop any professional activity, shall:

- *try with the best of their ability, courage, enthusiasm and dedication, to obtain a superior technical achievement, which will contribute to and promote a healthy and agreeable surrounding for all people, in open spaces as well as indoors;*
- *strive to accomplish the beneficial objectives of their work with the lowest possible consumption of raw materials and energy and the lowest production of wastes and any kind of pollution;*
- *discuss in particular the consequences of their proposals and actions, direct or indirect, immediate or long term, upon the health of people, social equity and the local system of values;*
- *study thoroughly the environment that will be affected, assess all the impacts that might arise in the structure, dynamics and aesthetics of the ecosystems involved, urbanized or natural, as well as in the pertinent socioeconomic systems, and select the best alternative for development that is both environmentally sound and sustainable;*
- *promote a clear understanding of the actions required to restore and, if possible, to improve the environment that may be disturbed, and include them in their proposals;*
- *reject any kind of commitment that involves unfair damages for human surroundings and nature, and aim for the best possible technical, social, and political solution;*
- *be aware that the principles*
- *bases poses a threshold of sustainability that should not be exceeded …*

Sustainable Development and Environment ...
Engineers shall strive to enhance the quality of the biophysical and socioeconomic urban environment and the one of buildings and spaces and to promote the principles of sustainable development. Engineers shall seek opportunities to work for the enhancement of safety, health, and the social welfare of both their local community and the global community through the practice of sustainable development. Engineers whose recommendations are overruled or ignored on issues of safety, health, welfare, or sustainable development shall inform their contractor or employer of the possible consequences.'

Codes of Ethics by national and international PEIs follow much along the same lines. For example, the Engineers Australia requires (tenet 6 of 9) that;

> *'Members shall, where relevant, take reasonable steps to inform themselves, their clients and employers, of the social, environmental, economic and other possible consequences which may arise from their actions'.*

Moreover, Engineers Ireland Code of Ethics includes three broad headings, the second of which is entitled 'Environmental & Social Obligations'. Five such obligations are mentioned. They require that *'members shall:*

- *at all times be conscious of the effects of their work on the health and safety of individuals and on the welfare of society. While acting as designers, operators or managers on projects, members shall strive to eliminate risks to health and safety during all project stages. Members shall also undertake to minimise or eliminate any adverse impact on the natural environment arising from the design and execution of all project work that they are engaged in.*
- *promote the principles and practices of sustainable development and the needs of present and future generations.*
- *strive to accomplish the objectives of their work with the most efficient consumption of natural resources which is practicable economically, including the maximum reduction in energy usage, waste and pollution.*
- *promote the importance of social and environmental factors to professional colleagues, employers and clients with whom they share responsibility and collaborate with other professions to mitigate the adverse impacts of their common endeavours.*
- *foster environmental awareness within the profession and among the public.*

The Code of Ethics for New Zealand engineers (IPENZ, 2005) includes guidelines under five headings including *'Sustainable Management and Care of the Environment'*, which states that;

> '*members shall recognise and respect the need for sustainable management of the planet's resources and endeavour to minimise adverse environmental impacts of their engineering activities for both present and future generations'*

and another under *'Commitment to Community Well-being'* which requires that;

> '*members shall recognise the responsibility of the profession to actively contribute to the well-being of society and, when involved in any engineering activity shall, endeavour to identify, inform and consult affected parties.'*

Commitments under the former heading include having due regard to;

> '*using resources efficiently, endeavouring to minimise the generation of waste and encouraging environmentally sound reuse, recycling and disposal, recognising adverse impacts of engineering activities on the environment and seeking to avoid or mitigate them'* and '*recognising the long-term imperative of sustainable management'.*

APPENDIX 5 EXTRACTS FROM SELECTED PEI ACCREDITATION GUIDELINES

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5.1. Ireland – Engineers Ireland

Extracts from accreditation criteria for engineering education programmes (Engineers Ireland, 2007).

At the professional (masters) level there are seven required programme outcomes that graduates must possess:

a) Knowledge and understanding of the mathematics, sciences, engineering sciences and technologies underpinning their branch of engineering.
b) The ability to identify, formulate, analyse and solve engineering problems.

Graduates should, *inter alia*, be able to;
(i) integrate knowledge, handle complexity and formulate judgements with incomplete or limited information;
(iii) identify and use appropriate mathematical methods for application to new and ill-defined engineering problems;

c) The ability to design components, systems or processes to meet specific needs.

Graduates should have, *inter alia*;
(i) knowledge and understanding of design processes and techniques and the ability to apply them in unfamiliar situations;
(ii) ability to apply design methods to unfamiliar, ill-defined problems, possibly involving other disciplines;
(iii) ability to investigate and define a need and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues;

d) The ability to design and conduct experiments and to apply a range of standard and specialised research tools and techniques.

Graduates should, *inter alia*, be able to;
iv) incorporate aspects of engineering outside their own discipline and to consult and work with experts in other fields;

e) Understanding of the need for high ethical standards in the practice of engineering, including the responsibilities of the engineering profession towards people and the environment.

Graduates should have, *inter alia*;
(i) ability to reflect on social and ethical responsibilities linked to the application of their knowledge and judgements;
(ii) knowledge and understanding of the social, environmental, ethical, economic, financial, institutional and commercial considerations affecting the exercise of their engineering discipline;
(iii) knowledge and understanding of the health, safety and legal issues and responsibilities of engineering practice and the impact of engineering solutions in a societal and environmental context;
(iv) knowledge and understanding of the importance of the engineer's role in society and the need for the highest ethical standards of practice;
(v) knowledge and understanding of the framework of relevant legal requirements governing engineering activities, including personnel, environmental, health, safety and risk issues.

f) The ability to work effectively as an individual, in teams and in multi-disciplinary settings, together with the capacity to undertake lifelong learning.

Graduates should have, *inter alia*;

(i) ability to recognise and make use of the interactions between the engineering technologies and the technologies associated with other disciplines and professions;
(ii) ability to consult and work with experts in various fields in the realisation of a product or system;
(vi) knowledge and understanding of concepts from a range of areas outside engineering.

g) The ability to communicate effectively with the engineering community and with society at large.

In addition Engineers Ireland outline six required 'Programme Area Descriptors'. Programme Area descriptors outline how each Programme Area, through the learning outcomes of its constituent modules, can contribute to the achievement of the Programme Outcomes by the engineering graduate. The Programme Areas are:

(a) Sciences and Mathematics

(b) Discipline-specific Technology

(c) Software and Information Systems

(d) Creativity and Innovation

In both research and design, students should have the opportunity to be involved in multi-disciplinary projects.

(e) Engineering Practice

Students need to be familiar with general engineering practice and with the particular operational practices of their discipline. Related to this is responding to real life situations and day-to-day management of complex engineering projects – supervising others, dealing with technical uncertainty and having awareness of codes of practice and the regulatory framework.

(f) Social and Business Context

Engineering is directed to developing, providing and maintaining infrastructure, goods, systems and services for industry and the community. Programmes need to develop an awareness of the social and commercial context of the engineer's work. This includes an understanding of issues relating to today's multi-cultural workforce, of socio-technology and of the constraints on technological developments imposed by health and safety, the environment, codes of practice, politics, the law and financial viability, management issues and the means by which the various risks may be assessed and managed. Students should be made aware of the various methods for the assessment of quality and fitness for purpose of engineering products and systems, and understand how to achieve these attributes in design and development. They should be given ample opportunity to analyse and discuss the ethical consequences of their decisions.

Society expects professional behaviour from its professional engineers and therefore programmes should enable students to become familiar with the expectations and standards inherent in professional codes of conduct.

5.2. United Kingdom

5.2.1. UK Engineering Council

Extracts from the UK Standard for Professional Engineering Competence (Engineering Council, 2010)

In the United Kingdom (UK), Engineering Council is responsible for the UK register of Chartered Engineers as well as Incorporated Engineers and Engineering Technicians. It prescribed accreditation competences are therefore incorporated by all the discipline specific institutions which come under its remit. It requires fours sets of general learning outcomes for all (BEng and MEng) graduates; Knowledge and Understanding, Intellectual Abilities, Practical skills, General transferable skills.

In addition, professional (MEng) graduates should display:

The ability to develop, monitor and update a plan, to reflect a changing operating environment

The ability to monitor and adjust a personal programme of work on an on-going basis, and to learn independently

An understanding of different roles within a team, and the ability to exercise leadership

The ability to learn new theories, concepts, methods etc in unfamiliar situations.

In addition the Engineering Council requires a range of specific learning outcomes of all graduates under five headings:

1. Underpinning science and mathematics, and associated engineering disciplines, as defined by the relevant engineering institution
2. Engineering Analysis
3. Design

   Design is the creation and development of an economically viable product, process or system to meet a defined need. It involves significant technical and intellectual challenges and can be used to integrate all engineering understanding, knowledge and skills to the solution of real problems. Graduates will therefore need the knowledge, understanding and skills to:

   - *Investigate and define a problem and identify constraints including environmental and sustainability limitations, health and safety and risk assessment issues;*
   - *Understand customer and user needs and the importance of considerations such as aesthetics;*
   - *Identify and manage cost drivers;*
   - *Use creativity to establish innovative solutions;*
   - *Ensure fitness for purpose for all aspects of the problem including production, operation, maintenance and disposal;*
   - *Manage the design process and evaluate outcomes.*
4. Economic, social, and environmental context

- *Knowledge and understanding of commercial and economic context of engineering processes;*
- *Knowledge of management techniques which may be used to achieve engineering objectives within that context;*
- *Understanding of the requirement for engineering activities to promote sustainable development;*
- *Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk (including environmental risk) issues;*
- *Understanding of the need for a high level of professional and ethical conduct in engineering.*

5. Engineering Practice (including):
   - *Ability to work with technical uncertainty.*
   - *A thorough understanding of current practice and its limitations, and some appreciation of likely new developments (only for professional (MEng) level graduates)*

5.2.1 Institution of Chemical Engineers (IChemE)

Extracts from A guide for university departments and assessors, for accreditation of chemical engineering degrees (IChemE, 2009)

The IChemE accredits degrees which fulfil the competencies for Chartered (i.e. professional) Engineer as required by the UK Engineers Council. In its accreditation procedures, the IChemE outlines four general learning outcomes (as per Engineering Council): Knowledge and understanding (They must have an appreciation of the wider engineering context. They must appreciate the social, environmental, ethical, safety, economic and commercial considerations affecting the exercise of their engineering judgement.), Intellectual abilities (They must be able to comprehend the ‘broad picture’ and thus work with an appropriate level of detail.), Practical skills and General transferable skills.

In addition, seven areas of learning must be clearly taught in all programmes (BEng/MEng) seeking IChemE accreditation (with an eight required for MEng programmes):

1. Underpinning mathematics and science
2. Core chemical engineering - They must be able to apply chemical engineering methods to the analysis of complex systems within a structured approach to safety.
3. Engineering practice
4. Design practice
5. Embedded learning (sustainability, SHE)* Students must acquire the knowledge and ability to handle broader implications of work as a chemical engineer. These include sustainability aspects; safety, health, environmental and other professional issues including ethics; commercial and economic considerations etc.
6. Graduates must be able to calculate and explain process, plant and project economics. They should also appreciate the need for high ethical and professional standards and understand how they are applied to issues facing engineers. They must be aware of the

priorities and role of sustainable development. They must be aware of typical legal requirements on personnel, processes, plants and products relating to health, safety and environment. It is expected that this material is consistently built upon and themes reinforced throughout the degree.

7. Embedded learning (general transferable skills) - Unlike all other categories, no minimum requirement in quantity is needed – rather ‘sufficient demonstration’ is required.
8. Complementary subjects
9. Advanced chemical engineering (depth, breadth, practice and design) (MEng only)

5.2.2 Institution of Mechanical Engineers (IMechE)

Extracts from the Institution of Mechanical Engineers Academic Accreditation Guidelines (IMechE, 2009)

The Institution of Mechanical Engineers specify five general learning outcomes for programmes. These are:

1. Underpinning Science and Mathematics and associated engineering disciplines
2. Engineering Analysis
3. Design
   - *Investigate and define a problem and identify constrains including environmental and sustainability limitations, health and safety and risk assessment issues*
   - *Ensure fitness for purpose for all aspects of the problem including production, operation, maintenance and disposal*
4. Economic, social and environmental context
   - *Understanding of the requirement for engineering activities to promote sustainable development*
   - *Awareness of the framework of relevant legal requirements governing engineering activities, including personnel, health, safety, and risk (including environmental risk) issues.*
5. Engineering Practice

In addition, the IMechE document lists ten qualification descriptors (‘QAA Qualification Descriptor for Masters degrees’) as ‘principal reference points for Masters degrees’ as stated by the Engineering Council ‘UK-SPEC publication’. These include the requirement that ‘Applicants will be able to:

> *Q5 Deal with complex issues both systematically and creatively, make sound judgements in the absence of complete data, and communicate their conclusions clearly to specialist and non-specialist audiences and will have the qualities and transferable skills necessary for employment requiring:*
>
> *Q9 Decision-making in complex and unpredictable situations*

5.3. Europe - FEANI

Extracts from the EUR-ACE Framework Standards for the Accreditation of Engineering Programmes (FEANI, 2009)

FEANI, the European Federation of National Engineering Associations, runs the EUR-ACE accreditation standard. A core of national associations in six jurisdictions currently adopt this framework, in France, Germany, Ireland, Portugal, Russia and the UK, though new national associations are reported to be soon about to join the system, which can also include in principle, non-European countries (Augusti, 2008).

The framework applies to both first (bachelors) and second (professional, masters) degrees and has six programme outcomes:

1. Knowledge and Understanding
2. Engineering Analysis

Second Cycle graduates should have the ability to solve problems that are unfamiliar, incompletely defined, and have competing specifications

3. Engineering Design

Graduates should be able to realise engineering designs consistent with their level of knowledge and understanding, working in cooperation with engineers and non-engineers. The designs may be of devices, processes, methods or artefacts, and the specifications could be wider than technical, including an awareness of societal, health and safety, environmental and commercial considerations.

Second Cycle graduates should have:

- *an ability to use their knowledge and understanding to design solutions to unfamiliar problems, possibly involving other disciplines*
- *an ability to use creativity to develop new and original ideas and methods*
- *an ability to use their engineering judgement to work with complexity, technical uncertainty and incomplete information*

4. Investigations
5. Engineering Practice - Graduates should be able to recognise the wider, non-technical implications of engineering practice, ethical, environmental, commercial and industrial

First Cycle graduates should have:

- *an awareness of the non-technical implications of engineering practice*
- *Second Cycle graduates should have:*
- *the ability to integrate knowledge from different branches, and handle complexity*
- *a knowledge of the non-technical implications of engineering practice.*

6. Transferable Skills

First Cycle graduates should be able to demonstrate awareness of the health, safety and legal issues and responsibilities of engineering practice, the impact of engineering solutions in a societal and environmental context, and commit to professional ethics, responsibilities and norms of engineering practice.

5.4. Germany - ASIIN

Excerpts of the requirements and procedural principles for the Accreditation and Reaccreditation of Bachelor's and Master's Degree Programmes in Engineering, Architecture, Informatics, the Natural Sciences and Mathematics (ASIIN, 2008)

ASIIN is the German institution responsible for examining and certifying Bachelor's and Master's programmes in engineering, in informatics/computer science, in the natural sciences and in mathematics. A learning outcomes based approach is undertaken at both bachelors and masters level.

Learning Outcomes – Bachelor's Degree Programmes in the fields of engineering, the natural sciences, informatics, architecture and mathematics. Specialist Competences include:

- *are capable of successfully conducting analytical or synthetic and developmental tasks, while taking into account scientific, technical, social, environmental, economic and societal ancillary conditions or standards, and using appropriate methods and suitable work techniques*
- *understand the effects their activities have on the environment and recognise the need for sustainable development*

Social Competences include:

- *are aware of the social and ethical responsibilities that underpin their actions, and of the professional ethical principles and standards that apply to their chosen discipline*

Learning Outcomes – Master's Degree Programmes in the fields of engineering, the natural sciences, informatics, mathematics and architecture have, in addition:

Specialist Competences

- *deepened the specialist and interdisciplinary knowledge they acquired during their first degree programme conferring a professional qualification, and / or broadened this knowledge through further methodological and analytical approaches*
- *gained the ability to formulate solutions to complex problems and tasks in a scientific context or for use in industry or society, and to critically analyse and further refine these solutions. Complex problems and tasks of this type exhibit the following characteristics:*
  - *their solution requires an analytical approach based on underlying principles they involve a broad range of sometimes conflicting factors, as well as different groups who are either affected by or have an interest in them they require different potential solutions to be weighed up they are uncommon in the relevant scientific or technical context, and fall outside pre-defined standards and paradigm solutions*
  - *acquired the skill of recognising future problems, technologies and scientific developments due to the depth and breadth of the competences they have mastered, and of subsequently including them in their work.*

5.5. France - Commission des Titres d'Ingénieur (CTI)

Guide d'Autoévaluation des Formations d'Ingénieurs (CTI, 2006). This document elaborates on the Standards-Cadre criteria defined by EUR-ACE, and develops, where applicable, the orientation proposed by the CTI.

5.6. USA - ABET

Excerpts of engineering programs effective for evaluations during the 2010-2011 accreditation cycle (ABET, 2009)

A total of eleven Program Outcomes are listed under ‘Criterion 3’. Those of relevance here are listed;

(c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability

(d) an ability to function on multidisciplinary teams

(f) an understanding of professional and ethical responsibility

(h) the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context

(j) a knowledge of contemporary issues

(k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

No further elaboration on the program outcomes is offered.

5.7. Canada - Engineers Canada/Ingénieurs Canada

Excerpts from accreditation criteria and procedures/Normes et procédures d’agrément (Engineers Canada/Ingénieurs Canada, 2009)

Engineers Canada employ twelve ‘Graduate Attributes’. Of most relevance is:

Impact of engineering on society and the environment: An ability to analyze social and environmental aspects of engineering activities. Such ability includes an understanding of the interactions that engineering has with the economic, social, health, safety, legal, and cultural aspects of society, the uncertainties in the prediction of such interactions; and the concepts of sustainable design and development and environmental stewardship.

The criteria include two other attributes which involve handling complexity;

Investigation: An ability to conduct investigations of complex problems by methods that include appropriate experiments, analysis and interpretation of data, and synthesis of information in order to reach valid conclusions.

Design: An ability to design solutions for complex, open-ended engineering problems and to design systems, components or processes that meet specified needs with appropriate attention to health and safety risks, applicable standards, and economic, environmental, cultural and societal considerations.

5.8. Australia – Engineers Australia

Excerpts from Engineers Australia national generic competency standards – stage 1 Competency standard for professional engineers (2006)

Engineers Australia requires that graduates possess competencies under three broad headings; Knowledge Base, Engineering Ability and Professional Attributes (Engineers Australia, 2006). Engineers Australia provide a requirement for the incorporation of sustainability and related issues to a level of detail and extent that is perhaps unmatched by any of the other institutions considered here. Relevant competencies are outlined below.

ENGINEERING ABILITY (6 sub headings, including:)

PE2.1 Ability to undertake problem identification, formulation, and solution

a. Ability to identify the nature of a technical problem, make appropriate simplifying assumptions, achieve a solution, and quantify the significance of the assumptions to the reliability of the solution

b. Ability to investigate a situation or the behaviour of a system and ascertain relevant causes and effects

c. Ability to address issues and problems that have no obvious solution and require originality in analysis

d. Ability to identify the contribution that engineering might make to situations requiring multidisciplinary inputs (see also PE2.2 and PE2.3) and to recognise the engineering contribution as one element in the total approach

PE2.2 Understanding of social, cultural, global, and environmental responsibilities and the need to employ principles of sustainable development

a. Appreciation of the interactions between technical systems and the social, cultural, environmental, economic and political context in which they operate, and the relationships between these factors

b. Appreciation of the imperatives of safety and of sustainability, and approaches to developing and maintaining safe and sustainable systems

c. Ability to interact with people in other disciplines and professions to broaden knowledge, achieve multidisciplinary outcomes, and ensure that the engineering contribution is properly integrated into the total project

d. Appreciation of the nature of risk, both of a technical kind and in relation to clients, users, the community and the environment

PE2.3 Ability to utilise a systems approach to complex problems and to design and operational performance

a. Ability to engage with ill-defined situations and problems involving uncertainty, imprecise information, and wide-ranging and conflicting technical and nontechnical factors

b. Understanding of the need to plan and quantify performance over the lifecycle of a project or program, integrating technical performance with social, environmental and economic outcomes

c. Ability to utilise a systems-engineering or equivalent disciplined, holistic approach to incorporate all considerations

d. Understanding of the process of partitioning a problem, process or system into manageable elements, for purposes of analysis or design; and of recombining these to form the whole, with the integrity and performance of the overall system as the paramount consideration

e. *Ability to conceptualise and define possible alternative engineering approaches and evaluate their advantages and disadvantages in terms of functionality, cost, sustainability and all other factors*

f. *Ability to comprehend, assess and quantify the risks in each case and devise strategies for their management*

g. *Ability to select an optimal approach that is deliverable in practice, and justify and defend the selection*

h. *Understanding of the importance of employing feedback from the commissioning process, and from operational performance, to effect improvements*

PE2.4 Proficiency in engineering design

c. *Experience in personally conducting a major design exercise to achieve a substantial engineering outcome to professional standards, demonstrating capacity to (among others):*

    - *ensure that the chosen solution maximises functionality, safety and sustainability, and identify any possibilities for further improvement develop and complete the design or plan using appropriate engineering principles, resources, and processes*
    - *ensure integration of all functional elements to form a coherent, selfconsistent system; check performance of each element and of the system as a whole*

PROFESSIONAL ATTRIBUTES (7 sub headings, including:)

PE3.3 Capacity for creativity and innovation

a. *Readiness to challenge engineering practices from technical and nontechnical viewpoints, to identify opportunities for improvement*

b. *Ability to apply creative approaches to identify and develop alternative concepts and procedures*

c. *Awareness of other fields of engineering and technology with which interfaces may develop, and openness to such interactions*

d. *Propensity to seek out, comprehend and apply new information, from wide range of sources*

e. *Readiness to engage in wide-ranging exchanges of ideas, and receptiveness to change*

5.9. New Zealand - Engineers New Zealand (IPENZ)

Excerpts from Graduate Competency Profiles (IPENZ, 2009) - Requirements for initial academic education for Professional Engineers (IPENZ, 2009a)

IPENZ requires among graduates of accredited programs eleven technical foundations, including:

- *Problem Solving: Able to formulate and solve models which predict the behaviour of part or all of: Complex engineering systems using first principles of the fundamental engineering sciences and mathematics*

- *Design and Synthesis: Able to synthesise and demonstrate the suitability and efficacy of solutions to part or all of: Complex engineering problems*
- *Management: Understands the accepted methods of dealing with uncertainty (such as safety factors) and the limitations of applicability of methods of design and analysis by being able to: Identify, evaluate and manage physical risks in complex engineering problems*

Furthermore, the document provides a definition of ‘complex engineering problems’:

Complex engineering problems means engineering problems which cannot be resolved without in-depth engineering knowledge and having some or all of the following characteristics:

- *Involve wide-ranging or conflicting technical, engineering and other issues*
- *Have no obvious solution and require originality in analysis*
- *Involve infrequently encountered issues*
- *Are outside problems encompassed by standards and codes of practice for professional engineering*
- *Involve diverse groups of stakeholders with widely varying needs*
- *Have significant consequences in a range of contexts*

Moreover, general responsibilities of an engineer are listed:

General responsibilities of an engineer include:

- *Social responsibilities including ethics, health and safety and other legislation*
- *Cultural responsibilities including, in New Zealand, the Treaty of Waitangi*
- *Environmental responsibilities including the need for sustainable development and design and legislative responsibilities*

In an accompanying document to ‘Graduate Competency Profiles’, thirteen curriculum requirements are listed, one of which is sustainability (IPENZ, 2009a):

Sustainability - Material on sustainability should be integrated throughout the curriculum, so students can consider the impacts of design upon society, nations and the environment. A systems approach is encouraged, including interdisciplinary teams, to teach sustainable engineering concepts.

The provider is required to demonstrate that the curriculum includes:

- *appropriate coverage of sustainable technologies and sustainable development methodologies.*
- *integrated consideration of the social and environmental effects of students’ future engineering activities.*

5.10. China - China Association for Science and Technology (CAST)

Although China is the largest producer of engineering graduates in the world, it has not historically had a formalised engineering programme accreditation system. In 2005 a number of Chinese government departments and relevant agencies, including the Ministry of

Personnel, the Ministry of Education, the Ministry of Construction, the Chinese Academy of Engineering and the China Association for Science and Technology, established a National Coordination Group for Reform of the Engineer System (CAST, 2007). This group was set up to research China's engineering framework and hence propose a plan of reform. It was also charged with taking the initiative to promote international mutual recognition of engineering qualifications with international peers.

The China Association for Science & Technology (CAST) is a national umbrella professional and academic organization, incorporating some 64 engineering societies. For example, among other initiatives, as part of an overall ultimate ambition to join the Washington Accord, it has overseen international links 'in mutual recognition of engineers and engineering educational programs' with other accreditation bodies since the 1990's including those between China Mechanical Engineering Society (CMES) and the UK based institutions, The Institution of Engineering & Technology (IET) and the Institution of Mechanical Engineers (IMechE), the Hong Kong Institution of Engineers (HKIE) and the American Mechanical Engineering Society (CAST, 2007) .

Since the end of 2005, there has been a move to establish an accreditation system for China's engineering programmes, and four disciplines were selected as bases for pilot accreditation; electrical engineering and automation, mechanical engineering and automation, chemical engineering and technology and computer engineering (CAST, 2007). Professor David Wood, who is advisor on IChemE accreditation and curricula reform to nine chemical engineering departments in China, has suggested that the changes being made in China 'are bringing programs to those of the mid to late 20th Century' [in the rest of the (Washington Accord) world], while issues such as 'safety and sustainable development are mostly neglected in Asia' (Wood, 2009). However, Wood points out in his keynote address to this Symposium (Wood, 2010) that China produces more chemical engineering graduates than the entire rest of the world, and wonders 'what hope is there for the rest of us', if as has been suggested by others (Cussler (2005), Armstrong (2006)), it is valid to say that lead countries (in terms of curricula content and structure) such as the USA and the UK are 30-40 years out of date?

5.11. India - National Board of Accreditation (NBA)

Excerpts of evaluation guidelines for NBA Accreditation of Undergraduate Engineering Programmes (NBA, 2009)

The NBA's accreditation procedures involve the allocation of 1000 points to programmes seeking accreditation. A learning outcomes approach does generally not appear to be applied, with just 100 of the available 1000 points based on 'Programme Educational Objectives'. Even within these, there are no explicitly specified objectives; programs are simply required to: '*Specify the program educational objectives (PEOs) and prepare a mapping between the PEO and their specified outcomes.*'

A further 125 points are available for Curriculum, which is subdivided into 'Contents of basic sciences, HSS, professional core and electives, and breadth' [40 points], 'Emphasis on laboratory and project work' [30 points], 'Curriculum updates and PEO reviews' [30 points] and 'Additional contents to bridge curriculum gaps'[25 points].

No further elaboration is given on for example what the professional core and electives might entail. The rest of the points are allocated for items such as available resources and facilities.

5.12. Japan Accreditation Board for Engineering Education (JABEE)

Excerpts from the criteria for Accrediting Japanese Engineering Education Programs Leading to Bachelor's Degree (JABEE, 2009)

JABEE require eight general 'learning and educational objectives' criteria in addition to individual program criteria against specific named fields of engineering. These include:

Criterion 1: Establishment and Disclosure of Learning and Educational Objectives

(1) For the purpose of fostering self-reliant engineers, the program must establish specific learning and educational objectives that concretize the contents of knowledge and abilities

(a) An ability and intellectual foundation to consider issues from a global and multilateral viewpoint.

(b) Understanding of the effects and impact of engineering on society and nature, and of engineers' social responsibility (engineering ethics).

(e) Design abilities to organize comprehensive solutions to societal needs by exploiting various disciplines of science, engineering and information.

5.13. Taiwan - Institute of Engineering Education Taiwan (IEET)

Excerpts from the Institute of Engineering Education Taiwan Accreditation Council Accreditation Criteria 2010

The IEET have nine criteria for accreditation, including one on 'Program Outcomes and Assessment' (Criterion 3). This criterion has eight requirements for graduates of accredited programs, including:

3.1.7 knowledge of contemporary issues; an understanding of the impact of engineering solutions in environmental, societal, and global contexts; and the ability to cultivate habits of life-long learning

3.1.8 understanding of professional ethics and social responsibility.

5.14. Hong Kong - The Hong Kong Institution of Engineers (HKIE)

Excerpts from the Professional Accreditation Handbook (Engineering Degrees) (HKIE, 2003)

HKIE require a number of criteria for accreditation, including duration, resources, entry levels, etc as well as one under Syllabus and Curriculum. These criterion incorporates three headings; Engineering Subjects, Mathematics and Complimentary Studies. There are five listed topic requirements under Engineering Subjects including;

- *Engineering Design and Synthesis - Its establishment as a separate topic can be used to demonstrate that it is a creative, iterative and often open-ended process and to also enable discussion of general design techniques and philosophy, as well as financial, quality, safety and environmental implications.*

Complementary Studies incorporates four headings, including:

1. Health, Safety and the Environment - The programme should demonstrate the importance of health, safety and environmental considerations to both workers and the general public.

2. The Professional Engineer - It is considered that students should be introduced to the role of the professional engineer in practice and their responsibilities towards the profession, colleagues, employers, clients and the public, particularly with reference to the impact of technology on society and with regard to ethical behaviour

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OUTCOMES ASSESSMENT IN CHEMICAL AND PETROLEUM ENGINEERING PROGRAMS

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Abstract: This paper describes the establishment, revision and assessment process for educational outcomes of chemical and petroleum engineering programs. This process is initiated by defining the Chemical and Petroleum programs outcomes to match the ABET (A-K) EC2000 criteria since program outcomes are the most important part of the educational process and must foster attainment of program educational objectives. Then a variety of direct and indirect assessment tools are proposed to determine how well graduates from both engineering programs are meeting the established outcomes. Three direct tools are implemented in the assessment process, namely; course / curriculum assessment, exit exam and capstone courses. The proposed indirect tools include internship advisor survey, course assessment by students, alumni survey, employer survey, students exit interview, and industrial advisory board. A schedule for collecting the assessment data to support the review of program objectives, outcomes, and curriculum is recommended. The overall assessment of achievement of program outcomes is performed by averaging the proposed assessment tools using a weighting factor designed to provide some judgment on the importance, quality, and number of feedbacks of each tool. Programs details and the results of the assessment process for one cycle are presented in this paper. Application of the outcome assessment results in the continuous improvement of both programs is also addressed.

Keywords; chemical engineering; petroleum engineering, outcomes assessment; assessment tools; curriculum evaluation; ABET accreditation

1. INTRODUCTION

The chemical and petroleum engineering department at the United Arab Emirates University was established in 1980. The mission of the Chemical and Petroleum Engineering programs is to meet the educational, research, and service needs of UAE society by providing programs and services of the highest quality. Also it contributes to the expansion of knowledge by conducting quality research and by developing and applying modern engineering tools and techniques that could play a significant role in the technical and economic development of the country.

The Accreditation Board for Engineering and Technology (ABET) is a professional accrediting organization in USA that accredits engineering, technology, computing and information science, and engineering related programs in the United States and internationally (Petrova et al., 2006).

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The objectives of ABET accreditation are to serve the public, industry, and the profession by stimulating the development of improved engineering education, encouraging new and innovative approaches to engineering education, and assuring that graduates of an accredited program are adequately prepared to enter and continue the practice of engineering. The new developed criteria of ABET for accrediting engineering programs EC 2000 (A-K) have changed the way that engineering programs prepare their graduates (Bai and Pigott, 2004). In order to survive in the future, each program has to develop a strategy to meet the new requirements specified in the EC2000 (A-K).

The Chemical (CHME) and Petroleum (PETE) Engineering programs at the United Arab Emirates University (UAEU) are designed to fulfill the ABET (A-K) EC2000 criteria. The Department of Chemical & Petroleum Engineering has established a well-defined process for outcomes assessment for the Chemical and Petroleum Engineering Programs in order to ensure that their graduates achieve the program educational objectives. Three direct tools are implemented in the assessment process, namely; course / curriculum assessment, exit exam, and capstone courses. The proposed indirect tools include internship advisor survey, course assessment by students, alumni survey, employer survey, students exit interview, and industrial advisory board (CHME Self Study Report, 2009; PETE Self Study Report, 2009).

This paper aims to describe the establishment, revision and assessment process for educational outcomes of chemical and petroleum engineering programs.

2. PROGRAM OUTCOMES

The College of Engineering at UAEU was inaugurated in September 1980 with two academic departments; the Civil Engineering Department and the Chemical & Petroleum Engineering Department. The Chemical & Petroleum Engineering department continued to offer a joint degree in Chemical & Petroleum Engineering until 1988, and since then separate degrees in Chemical Engineering and Petroleum Engineering have been offered. During that period, substantial equivalency to ABET accredited Chemical and Petroleum Engineering programs was granted twice. The programs are now under a new review by ABET and it is hoped that it will be granted full accreditation.

The program outcomes were established on the basis of the needs of the country, outcomes of other institutions, ABET A-K criteria, university and college strategic plans, feedback from industry through Open House activities, comments of students through interviews and other contacts, and better fulfillment of the outlined objectives and the constituencies' needs. After several revisions and input from the CHME Department Council and the College administration, the CHME and PETE program outcomes were consolidated to become identical to the required ABET A-K outcomes of Criterion 3 (i.e., outcome assessment) of Engineering Criteria 2000, which is required for continuous accreditation of the programs. Upon graduation every student in each program will have achieved all of the intended program educational outcomes and as shown in Table 1 (CHME Self Study Report, June 2009, PETE Self Study Report, June 2009).

These outcomes are self-explanatory; they relate to the skills, knowledge, and behaviors that students acquire in their matriculation through the CHME and PETE programs. They also describe what students are expected to know and be able to do by the time of graduation. The department reviews its outcomes every 3 years based on changes in ABET criteria and feedback received from constituents.

Table 1: Chemical and Petroleum Engineering Programs Outcomes

Outcome	Chemical Engineering Program	Petroleum Engineering Program
A	Thorough grounding in chemistry, physics, biology, math and engineering subjects such as fluid mechanics, thermodynamics, heat transfer, mass transfer, and reaction kinetics; and the ability to apply knowledge of these subjects in chemical engineering practice.	Competency in mathematics through differential equations, linear algebra, probability, and statistics; and engineering subjects including strength of materials, fluid mechanics, and thermodynamics; and ability to apply these courses to practical petroleum engineering problems.
B	An ability to design and conduct different chemical engineering experiments, as well as to analyze and interpret data.	Ability to design and conduct different petroleum laboratory experiments, as well as to analyze and interpret laboratory and field data.
C	An ability to analyze, design, and control a system, component and/or process dealing with fluids handling, separation, and chemical/biochemical reactions to meet desired needs	Competency in petroleum engineering including design and analysis of well systems, procedures for drilling and completing wells, characterization and evaluation of subsurface geological formations, design and analysis of systems for producing, injecting, lifting and handling fluids; application of reservoir engineering principles and practices for optimizing resource development and management; use of project economics and resource valuation methods for design and decision making under conditions of risk and uncertainty.
D	An ability to work and interact effectively in groups/teams which have diverse personalities, cultures, and backgrounds.	Ability to work and interact effectively in groups/teams which have diverse personalities, cultures, and backgrounds.
E	Ability to identify, formulate, and solve chemical engineering problems	Ability to identify, formulate, and solve practical petroleum engineering problems.
F	An understanding of professional and ethical responsibility	Understanding of professional and ethical responsibility.
G	Ability to develop effective oral, written, and interpersonal communication skills.	Ability to develop effective oral, written, and interpersonal communication skills.
H	Ability to evaluate the potential risks, i.e. consequences and probabilities of engineering solutions which may affect society and the environment.	Ability to evaluate potential risks, i.e. consequences and probabilities of engineering solutions which may affect the society and environment.
I	A recognition of the need for and an ability to engage in independent-learning and life-long learning	Recognition of the need for and an ability to engage in independent-learning and life-long learning.
J	A knowledge of contemporary issues	Knowledge of contemporary issues related to the petroleum industry.
K	An ability to use of computer software such as spreadsheets, mathematics packages, word processors, and design packages in solution of chemical engineering problems.	Ability to use computer software such as spreadsheets, mathematics packages, word processors, reservoir simulation models, and design packages in solution of petroleum engineering problems.

Currently, the CHME and PETE programs take a minimum of ten semesters to complete the 168 credit hours required for graduation. They include the University General Requirements (30 credits), General Culture and Free Electives (12 credits), College Requirements (38 credit hours), Specialization Requirements (73 credit hours), and Industrial Training (15 credit hours).

3. CHME & PETE PROGRAM OUTCOMES ASSESSMENT

3.1 Achievement of Program Outcomes

The Department of Chemical & Petroleum Engineering has established a well-defined process for outcomes assessment for the Chemical and Petroleum Engineering Programs in order to ensure that its graduates achieve the program educational objectives. Figure 1 presents the proposed framework for the establishment of the program objectives and outcomes assessment process. The significant feature of this proposal is indicated by the two loops making up the assessment process.

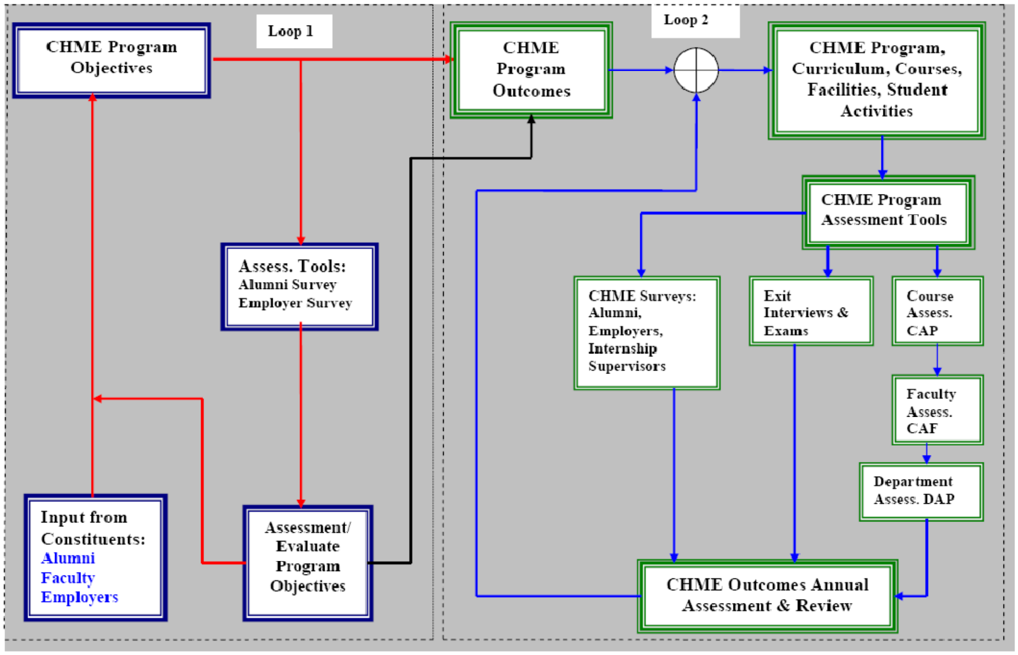


Figure 1: CHME Program Outcomes Assessment Framework

The first loop (Figure 1) encloses the cycle of program objectives assessment. The constituencies (alumni, employers and faculty) provide the input of the objectives in terms of surveys and direct contact in Open House meetings. The input data is gathered and analyzed before it can be used to evaluate and review the objectives. In addition, this information is incorporated into the determination and modification of the outcomes that are required to achieve these objectives, as illustrated in Figure 1. The second loop is composed of the assessment and evaluation of the achievement of the outcomes. Based on the outcomes, the program curriculum, courses, and student activities are designed. Data obtained from the assessment activities is central to both loops and it also drives the program toward improvement. Nine assessment tools are used annually to evaluate the program outcomes. The assessment tools are classified as direct tools (Course / Curriculum Assessment, Exit Exam, Capstone Course) and indirect tools (Internship Advisor Survey, Student Assessment of Course, Alumni Survey, Employer Survey, Students Exit Interview, Industrial Advisory Board).

3.2 Course and Curriculum Assessments

The curriculum assessment process accumulates individual contributions from selected courses in the CHME and PETE programs to the obtain program outcomes for the purpose of assessing the entire curriculum. By mapping the program outcomes to the program objectives, recommendations could be made at the end of the process to improve the program outcomes as well as the program educational objectives. The process then starts all over again.

3.2.1 Assessments of Course Outcomes

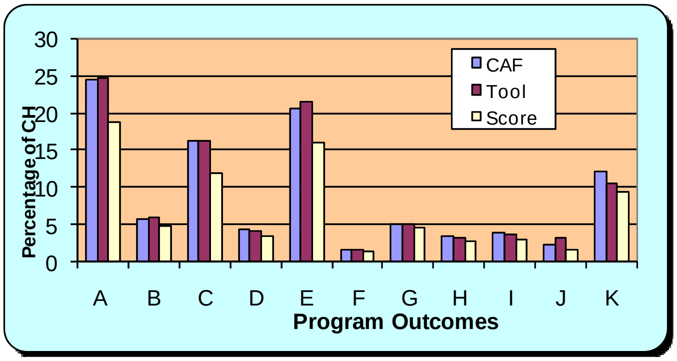
The process starts by developing the Course Syllabus. The course syllabus contains the course outcomes mapped to the program outcomes. The measure for assessment is the Course Assessment by Faculty (CAF), an in-house developed Excel program that includes three performance measures: Students, Faculty, and Quantitative. The CAF reports of the selected core courses were compiled for each year and their corresponding outcomes were measured using the following indices.

1. *Course Assessment by Students (CAS):* At the end of each semester, students evaluate the course using the CAS Survey Forms. The survey lists the course outcomes as presented in the course syllabus. The survey asks students to evaluate each course outcome based on a 1-5 scale, where 1 is poor and 5 is excellent. The basis of evaluation should be on student's feeling of how the class has helped him/ her to achieve the abilities, attributes, and skills as described in the outcomes. The results of the survey were collected and analyzed as the CAS is considered one of components in the evaluation process.
2. *Quantitative Assessment of the Course:* Each course in the program contributes to some extent to the major intended outcomes of the Department. The relative weight for each related outcome is decided by the faculty member teaching the course (TARGET). Then these relative weights were fed into the CAP (Course Assessment by Program: another Excel program developed by the Department). This program breaks down each activity in terms of A-K criteria of the Department.

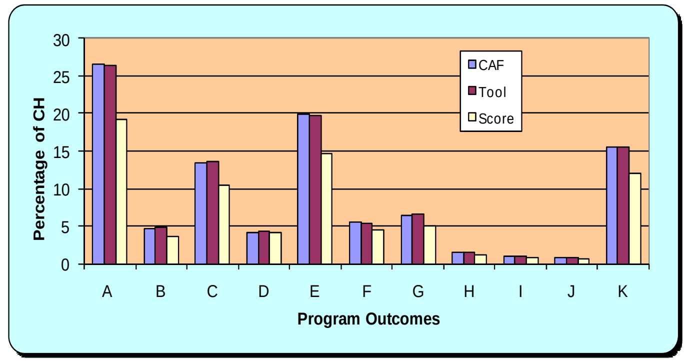
3.2.2 Assessments of Curriculum Outcomes

The results from CAP of some course selected every semester were fed into the Department Assessment Program (DAP) which refers to assessment of curriculum outcomes: an Excel program developed by the Department which adds up all outcomes measures in all the courses in the Department in terms of A-K contribution designated as CAF (intended outcome), TOOL (student assessment components) and SCORE (student performance relevant to TOOLS used). Thus, the overall picture of the Department is produced in terms of number of credit hours the department spends in each criterion. The Focus Groups study the relevance of courses to A-K and the student performance in the courses and come up with metric goals for each outcome that illustrate the level of quality of outcomes achievement felt necessary to produce graduates that ultimately achieve the Educational Objectives upon their graduation.

The distribution of A-K criteria in terms of credit hours for Chemical and Petroleum Engineering Programs at the end of December 2008 is illustrated in Figure 2. These were prepared from ten core courses in chemical program and from eleven selected core and elective courses in petroleum engineering program. In Figure 2, CAF is the distribution of the weights of A-K criteria by the faculty member as per the subjects covered. TOOL is the extent of student assessment for each activity according to the A-K criteria. SCORE is actually what the student has achieved in the course activities. It can be observed from Figure 2 that the CHME and PETE curriculums focus mostly on the ABET criteria A (knowledge), E (Engineering Problems), and to a lesser extent on C (Design) and K (Techniques, Skills and Tools) as the most important outcomes to be achieved. In the second rank, it focuses on criteria B (Experiments and Data Interpretation), D (Functioning in Teams), F (An understanding of professional and ethical responsibility), and G (Ability to communicate). Based on the Course Assessment by Faculty (CAF) reports, the results of ***score to tool ratio*** versus the individual A-K outcomes for the selected courses for year 2008 are listed in Table 2. It can be observed that in all criteria this ratio is well balanced (over 3.5 out 5) except outcome J in CHME program, which is slightly below the target, and thus it could be claimed that the instructors have been successful in setting their tool elements for the selected courses. More emphasis should be placed on criterion B in PETE program to improve the score/tool ratio.



(a)



(b)

Figure 2: The percentage distribution of credit hours in 2008 (a) Chemical (b) Petroleum

Table 2: Curriculum Assessment of 2008

Program	Outcomes											
	A	B	C	D	E	F	G	H	I	J	K	Average
CHME	3.9	4.1	3.8	4.4	3.8	4.7	4.7	4.5	4.5	3.4	4.5	4.2
PETE	3.7	3.5	3.8	4.2	3.7	4.4	3.7	4.6	5.0	3.9	3.8	4.0

3.3 Exit Exam

An exit exam encompassing all the core courses in the Chemical and Petroleum Engineering Programs with 50 questions was designed in order to assess the students in their final semester. This exam is conducted during the last portion of Graduation Project II course. Exit exam questions were also mapped to ABET criteria and assessment of the exam is included in the overall assessment.

3.4 Capstone Course

The capstone design course is spread over two semesters as Graduation Project I and Graduation Project II. The CHME and PETE programs use the results of the GP II (bulk of design work) only in the assessment process. It was found that students performed quite well in achieving the program intended outcomes.

3.5 Internship Advisor Survey

All CHME and PETE students are required to join the industrial training program after they complete at least 114 credit hours. Each trainee spends a full semester (about four months) in an industrial setting. The industrial supervisor is asked to complete a survey to assess the trainee's abilities, attitudes and skills relevant to the educational outcomes of the CHME and PETE programs.

3.6 Alumni Survey

The alumni survey was designed to provide the information needed by the CPE Department to measure the intended outcomes for the CHME and PETE programs. For this purpose two types of alumni surveys were conducted: (1) For fresh graduates with less than 3 years experience, and (2) For senior graduates with three years experience or more. The fresh graduates' survey has 11 stated items that match the A-K outcomes of the CHME and PETE programs. Each item was quantitatively evaluated from the standpoints of strength, career-wise, and the preparation that the program has offered. The senior alumni survey was designed to encompass two parts; the first part considers the attributes addressed by the program objectives and the second part considers the abilities, attributes, and skills addressed by the A-K outcomes of the programs. The survey was analyzed to determine the "strength" level for each of the stated items. The Alumni were asked to evaluate all items as “Very Weak”, “Weak”, “Average”, “Strong”, or “Very Strong".

3.7 Employer Survey

The survey was conducted to assess how well CHME / PETE graduates meet the program outcome criteria as judged by their employers. This survey is considered to be one of the important feedback tools from the program constituencies. The Employer Survey contains two sets of questions; the first set includes 5 questions that conform to the program educational objectives and the second set includes 11 questions that conform to the program outcomes. The results of employers' assessment of the CHME and PETE programs outcomes through the performance of its graduates are achieved by computing the weighted average of the survey to every program A-K outcome.

3.8 Exit Interview

The Exit Interview was designed to get some comments directly from graduating students. In the interview, graduating seniors were asked questions that focus on their opinions regarding their experience at UAEU and their perception of achieving the CHME and PETE programs outcomes (as reflected by the ABET outcomes). The results of this interview are qualitative and thus do not have a weight in the overall assessment of the program. However, students’ comments were considered in the continuous improvement cycle of the program.

3.9 Overall Assessment of Achievement of Program Outcomes

The following section summarizes the results of the assessment for quantitative data gathered on a regular basis that were used to assess the quality of achievement of the outcomes and analysis of those assessment results. The assessment tools weight distribution was selected in accordance to the level of strength of the tool as follows: Curriculum (30%), Employer Survey (25%), Internship (5%), Capstone Courses (10%), Alumni Survey (20%), Exit Exam (5%) and Student Assessment of Course (5%). The data were aggregated to evaluate individual program outcomes separately. The following success criteria for each outcome were suggested: 1. **S**uggested **I**mprovement: The program outcome has been met, but recommendations for some improvement may be suggested. The score is between 3.5 and 5.0 for any of the surveys except Exit Exam and Course Assessment by Students (CAS). The score for the Exit exam and CAS should be above 60%. 2. **N**eeds **I**mprovement: The program outcome has been marginally met. Improvement should be suggested and implemented. The score is between 3.0 and 3.49 for any of the surveys except Exit Exam and (CAS). The score for Exit exam and CAS is between 50%-60%. 3. **M**ajor **I**mprovement: The program outcome has not been met. Major improvement should be suggested and implemented. The score is less than 3.0 for any of the surveys except Exit Exam and (CAS). The score for Exit exam and CAS is less than 50%.

Table 3 summarizes the results of all assessment tools that were conducted to evaluate the CHME and PETE program outcomes in year 2008.

4. CONTINUOUS IMPROVEMENT

Further improvement in the curriculum outcomes assessment can be achieved by some combination of the following; (a) implementation of focus groups recommendations, (b) upgrading of course materials, (c) introducing new software packages to solve engineering problems, (d) emphasizing team work, (e) shifting to industry-oriented design problems in capstone courses, and (f) introducing new courses if necessary. The results of the overall outcome assessment for year 2008 shown in Table 3 indicate that all A-K program outcomes have been met. However, more work seems to be needed to improve outcome J in chemical engineering program and outcomes B and C in petroleum engineering program. Recommendations made by focus groups for CHME and PETE courses were partially deduced from the results of the various assessment tools used in the proposed process of program outcomes assessment. These recommendations are to be implemented in the specified courses during the subsequent semesters.

Table 3: Summary CHME and PETE Programs Outcome Assessment Data, year 2008

Outcomes	Assessment Tools CHME Program								Assessment Tools PETE Program							
	Curriculum	Capstone	Exit Exam	Internship	CAS	Alumni S.	Employer S.	Total	Curriculum	Capstone	Exit Exam	Internship	CAS	Alumni S.	Employer S.	Total
Wt%	**30%**	**10%**	**5%**	**5%**	**5%**	**20%**	**25%**		**30%**	**10%**	**5%**	**5%**	**5%**	**20%**	**25%**	
A	3.9	4.2	3.2	3.7	4.3	3.8	4.0	**3.9**	3.7	4.3	3.2	2.9	4.4	4.2	3.7	**3.8**
B	4.1	3.9	2.9	3.4	4.1	3.6	3.9	**3.8**	3.5	4.2	2.4	2.5	3.6	4.3	3.4	**3.6**
C	3.9	3.9	3.2	3.1	4.0	3.5	3.6	**3.7**	3.8	4.2	3.3	1.0	4.0	4.1	3.4	**3.6**
D	4.4	4.4	NA	4.0	4.3	4.0	4.4	**4.3**	4.2	4.3	2.2	3.3	4.1	4.4	4.4	**4.3**
E	3.9	3.9	3.1	3.5	4.2	3.8	4.0	**3.9**	3.7	4.2	2.9	1.8	4.1	4.4	3.7	**3.8**
F	4.6	4.4	5.0	4.0	4.3	3.9	4.1	**4.3**	4.0	4.5	2.7	3.3	3.1	4.1	4.3	**4.0**
G	4.5	4.2	3.7	4.0	4.1	3.8	3.9	**4.1**	3.7	4.3	2.6	3.3	3.3	4.2	3.9	**3.8**
H	4.3	3.9	2.3	3.8	4.0	3.6	3.8	**3.9**	3.9	4.2	3.0	2.4	3.6	4.0	3.7	**3.8**
I	4.4	4.4	2.1	3.8	3.8	3.8	4.0	**4.0**	3.8	4.5	4.2	2.9	3.6	4.1	3.7	**3.9**
J	3.4	3.9	2.2	3.5	3.6	3.4	3.9	**3.5**	3.8	4.2	3.2	2.8	3.4	4.1	3.7	**3.8**
K	4.5	4.4	3.4	3.7	4.1	3.9	3.8	**4.1**	3.8	4.5	2.9	2.9	3.9	4.3	3.9	**3.9**

5. CONCLUSION

A systematic approach is proposed in this study for the assessment of CHME and PETE programs' educational outcomes. Direct and indirect assessment tools were recommended and implemented to achieve this purpose. The results of the proposed outcomes assessment process can lead to identification of points of weaknesses and strengths in the program which could then be translated into actions for the improvement of the CHME and PETE programs. The evaluation process developed in this work for the CHME and PETE programs at UAEU is recommended for implantation in other engineering disciplines and subdiscplines. .

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THE VALUING OF CREATIVITY IN THE WORKPLACE ROLES OF ENGINEERING RESEARCH GRADUATES

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Abstract: This paper reports on a study that explored the beliefs of twenty-two industry-based employers of Mechanical and Chemical Engineering Higher Degree Research (EHDR) graduates about the value of these graduates to the engineering workplace. Once the commonly known generic employability attributes were set aside, the findings revealed that creativity was an essential factor in employers' decisions to accommodate these graduates. The employers' comments suggested that they valued knowledge and creative problem-solving skills gained in HDR candidature but feared that EHDR graduates would display attributes popularly associated with creative genius, and this concern reduced their willingness to accommodate these graduates. This highlights the value of creative skills and attributes, the hallmarks of HDR activity, to the overall employability of EHDR graduates in innovative enterprises, but reveals a barrier to industry engagement that is based on myth.

Keywords; Doctoral education, employability, graduate attributes, creativity.

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1. INTRODUCTION

Higher degree by research (HDR) qualified engineers are rare in Australia, with 2.6% of the engineering workforce qualified at the engineering doctorate level (Engineers Australia 2008). However, 24% of all doctoral graduates stated that they were employed in engineering-related industries (Neumann et al., 2007). Despite their industry destinations, Engineering HDR graduates have been commonly painted by employers as poorly prepared for industry work, lacking key professional capabilities including teamwork, communication, managerial, time management and problem-solving skills (Akay, 2008; Mann et al., 1994; Tyler, 1998).

The present study looked beyond employer demands for generic professional skills to explore the beliefs and experiences of employers who have successfully engaged EHDR graduates. Creativity was found to be a valued employability attribute, yet one that the employers feared.

1.1 Creativity at work

Creativity is manifest as a quality of a person, product, and cognitive process. It is evident in the achievement, by the use of creative cognitive processes, of an original product, process or idea that is fit for purpose (Amabile, 1983; Torrance, 1988; Woodman et al., 1993). Amabile (1983) defined the notion of originality as both the outcome and the process by which it is achieved: 'A product or response will be judged as creative to the extent that (a) it is both a novel and appropriate, useful, correct or valuable response to the task at hand, and (b) the task is heuristic rather than algorithmic' (Amabile, 1983, p. 33). Innovation is defined as 'the successful implementation of creative ideas within an organisation' (Amabile et al., 1993; Amabile et al., 1996), including the implementation of creative ideas generated elsewhere (Amabile et al., 1996; Woodman et al. 1993).

Amabile (1983) presented a model for the production of creative outcomes that integrates three essential components. Domain-relevant skills form the pool of knowledge a person draws upon when undertaking a problem-solving task; in the case of EHDR graduates these are the engineering knowledge and skills honed in HDR candidature. Knowledge of this type is frequently unrecognised as essential to creative outcomes (Woodman et al., 1993). Creativity-relevant skills form the thinking processes that control decisions about the way the search unfolds. Task motivation consists of the interests and drive a person has to persevere in a task. Figure 1 lists the elements of each component and the variables on which each element is dependent.

Domain-relevant skills	**Creativity-relevant skills**	**Task Motivation**
Includes: • Knowledge about the domain • Technical skills required • Special domain-relevant "talent" Depends on: • Innate cognitive abilities • Innate perceptual and motor skills • Formal and informal education	Includes: • Appropriate cognitive style • Implicit or explicit knowledge of heuristics for generating novel ideas • Conducive work style Depends on: • Training • Experience in idea generation • Personality characteristics	Includes: • Attitudes toward the task • Perceptions of own motivation for undertaking the task Depends on: • Initial level of intrinsic motivation toward the task • Presence or absence of salient extrinsic constraints in the social environment • Individual ability to cognitively minimize extrinsic constraints

Figure 1: Components of creative performance (Amabile 1983, p. 68)

1.2 Notions about the creative individual

The notion persists that creativity is a flash of insight or special, mysterious, irrational and difficult to manage quality (Becker, 1992; Rickards, 1999). At its extreme, this view of creativity was explained as a form of divine mania or as a psychopathological state.

Biographical studies into the lives and mental states of eminent creative geniuses, usually artists and writers, revealed problematic personal attributes such as eccentricity, isolationism, obsession, and madness that still form a popular stereotype of the highly creative genius.

Since the 1950s, research both moved away from biographical study and focused on the correlates of scientific creativity, which were identified as broad interests, attraction to complexity, high energy, independence of judgement, autonomy, intuition, self-confidence, persistence, curiosity, intellectual honesty, and an internal locus of control (Woodman et al., 1993), and openness and flexibility, arrogance and hostility (Feist, 1999). No empirical evidence supports a hypothesis that personality characteristics are predictors of creativity, and according to Feist (1999), only openness and flexibility are strongly associated with scientific creativity.

As well as extensive domain knowledge, the cognitive factors associated with the creative process (Woodman et al., 1993) include the capability

- to generate many and varied ideas, combined with divergent thinking to generate fluent, flexible, original and elaborated ideas by transforming knowledge and re-envisioning situations;
- for convergent thinking to produce not only original, but useful and appropriate outcomes;
- to tolerate ambiguity so that the creative person is not tempted to resort to conventional, and previously unsuccessful, patterns in frustrating problem-solving situations.

2. THE STUDY

The views of twenty-two industry employers of Mechanical and Chemical Engineering research Masters and PhD graduates in two Australian cities were explored using Grounded Theory methodology (Glaser and Strauss, 1967). Interview participants covered a broad range of roles in organisations ranging in size from 25 employees to several thousand and engaged in a variety of principal activities. The following six questions were used as prompts to discussion:

- Why do you decide to employ a postgraduate engineer for some positions? (What sorts of positions require postgraduate education and training?)
- What attributes do you believe postgraduate engineers should bring to a position?
- What attributes do you believe postgraduate engineers actually do bring to a position?
- Are you ever surprised by what a postgraduate is or is not able to do?
- If you had the opportunity to provide feedback to a university about their postgraduates' abilities, what would you say?
- If you had the opportunity to provide feedback to postgraduate candidates about their value to employers, what would you say?

Participants were encouraged to comment, from their experiences, on anything they believed relevant to the topic. This paper presents interesting observations made from the interview data.

2.1 Innovator role types

The roles the employers believed suitable for EHDR graduates in their organisations were distinguished by the degree of originality required in their performance outcomes (Table 1), ranging from the innovative adaptation of existing, imported products or processes (innovative adapter role) to the envisioning of potential future developments with no possibility for immediate implementation (visionary innovator role). An intermediate role, niche innovator, required an original outcome but employers of these engineers emphasised the need for constraint imposed by limited availability of resources (Adams et al., 2008). Niche innovators typically worked in manufacturing and consulting engineering firms.

Table 1: Key advanced engineering innovator role types, their purposes and tasks, ranging from least creative (innovative adaptor) to most creative (visionary innovator)

Increasing demand for originality in innovative process and outcome	Innovator type	Purpose	Engineering HDR graduate tasks
↓	Innovative adapters	To maintain product or service relevance	Search for, identify, assess and adapt readymade products
	Niche innovators	May include the above, plus… To provide competitive advantage in the marketplace	Devise and develop new to world products or processes Adapt and maintain new products
	Visionary innovators	Some or all of above, plus… To predict future scenarios and anticipate developments	Some or all of above, plus… Anticipate future development scenarios Build knowledge base for potential future developments

2.2 The value of knowledge and creativity skills

The employers entertained two notions of creativity in parallel. Firstly, much as modelled by Amabile (1983), they identified the value of EHDR graduates' domain and creativity-relevant skills to production of original outcomes. Secondly, they associated EHDR graduates' creativity with personal characteristics popularly linked to creative genius. The quotes below are a sample of many comments made by the employers associating EHDR graduates with domain-relevant and creativity skills.

The ability to generate many and varied ideas and use extensive domain knowledge was important to problem-solving:

> *Specialists are thinkers ... in the areas of scenario planning ... helping management to think hard and you know, sort of put plans in place for contingencies or issues or a resource drying up for example. […] bringing a lot of research based knowledge of what has been done before. (Emp 9C)*
>
> *And I know they have the skills and power to drill into those problems more so than others, and solve it. [A PhD employee] because he's had research experience, his maths skills are honed to a greater detail and his use of a particular software or software types was actually more honed. […] he can think outside the square and think about the broader issues. (17)*

They valued EHDR graduates' creative skills of divergent thinking and tolerance of ambiguity:

> *A lot of the time you do need to think a little bit left of field and maybe try for a while and it doesn't work out, …, you might learn something else in the process. ... it's not really a clear science, there's a lot of theory of how to get something ... but getting something that works most effectively, it's a little bit of a black art… You've got to be able to think a little bit laterally. (3)*

Creative skills in problem formation and re-envisioning were acknowledged, including an ability to move beyond conventional engineering approaches:

> *But certainly in attitude it was preparedness to attack problems that they'd not seen before, cause most of the problems we were dealing with we hadn't seen before. Willingness to learn, an open-minded approach, ability*

> *to think, preparedness to think. We didn't want someone whose views were 'this is the only way to do something'. (8)*

They sought EHDR graduates who were able to think heuristically and achieve original outcomes:

> *I suppose novel means in that sense thinking outside the box. ... What we're talking about is coming up with a novel idea or a different approach to a problem which is not the norm and that's different. (19)*

EHDR graduates were viewed as able to transfer deep knowledge from one problem-solving area to another, and had confidence (task motivation) to think differently from traditional engineering problem-solving approaches:

> *'I think he* [EHDR graduate] *got that through that experience doing post graduate work. So you don't have the time when you're doing normal engineering as a graduate employee to develop a broad enough perspective to be able to take the knowledge in one field and being able to flop it across to another…and also to be able to dig down deeper' (Emp 2A).*

Some employers also recognised Amabile's third component of creative performance: task motivation displayed in an intrinsic drive to discovery. This is evidenced in the following character descriptions of attitude to problem-solving activity:

> *a postgraduate degree program, has shown that he or she can exhibit the sort of skills and attributes that we're looking for, which includes primarily a rampant curiosity and an ability to go where others haven't gone…(10D)*

2.3 Fear of misfits

Despite their recognition that EHDR graduates possess education, knowledge and skills of use in the abovementioned roles, all the employers harboured reservations about EHDR graduates' personal suitability for their workplaces. They provided many comments about the personal characteristics of graduates that revealed understandings and opinions about Engineering HDR candidates, the HDR experience and academia that suggest the employers entertained popular notions of stereotypical creative genius.

While some employers viewed EHDR graduates as systematic and procedural, others viewed them as obsessed, driven and unusual, with allusions to madness:

> *... a 'mad professor', you know – a little bit autistic… Tendencies to zoom in on things in great detail – perhaps put the blinkers on and drill into a problem. […] And that mad professor part comes from getting too caught up in a particular topic, and to the detriment of everything else.*

The persistence and determination needed to pursue isolated study on a narrow topic served as evidence that HDR graduates were driven by perfectionism ('Rolls Royce solution', Emp 5A) and self-interest. Furthermore, the image of a solitary research student, colourfully described by one employer as 'sitting in a back room somewhere for five years under a 40 watt light bulb' (Emp 18E), was feared as evidence of a non-collaborative approach in problem-solving and an attitude of secrecy and individual ownership of knowledge and problem solutions. These suspected characteristics underpinned the employers' concern that extended commitment to HDR study deprived an engineer of valuable work and life-enhancing experiences, particularly those that would engender workplace-relevant pro-social attitudes:

> *…someone who is comfortable with staying in a laboratory for 4-5 years and perhaps, … they're dealing with a relatively smaller number of people in a fairly protected academic environment… (7)*

Engineering researchers were characterised as quirky and self-absorbed, and unlike regular engineers:

> *It seems to be viewed by the rest of the organisation with a deal of amusement, I guess, that they [researchers] are so focused on the academia and papers published and when they have any presentations or whatever they put letters after their names, whereas in the engineering field we tend not to.(22CHR)*

Employers suspected EHDR graduates are arrogant or egotistical:

> *If they come in thinking I've got a PhD so everybody is going to listen to what I say, I think they've got a big surprise coming because sometimes a tradesperson has got more knowledge… but if they are just, you know because they are PhD's thinking 'Well I'm so good, people want to come and talk to me', I think people wouldn't bother. (9C)*

Their intelligence was also associated with egocentrism that impacted on co-workers, suggesting an image of the mad genius as social misfit:

> *Because it is day to day stuff very often, it is day to day. And as a manager of people, which is my job, you know, if you have got two or three people who are sort of prima donnas and stuff like that, oh gee. And for such a marginal, they might be brilliant, by such a marginal improvement to the job that we do, to the distraction and the lack of everything else that goes with it. It is just not worth it. (15D)*

The social difficulties were partially hypothesised as a preference for ideas over people, and this was inferred as particularly problematic in consulting work:

> *If you put them out of their comfort zone a little bit, they find in themselves that they may struggle and they think, 'I don't want to do it – not interested. I don't want to talk to clients; don't want to deal with them – they annoy me. I just want to do my work. I want to solve problems.' The relationship is all fluffy – they want to deal with the hard core engineering issues. (Emp 17)*

Exposure to the hard-driving, 'cutting-edge' real world of work was viewed as a socially maturing process, and EHDR graduates were viewed as potentially socially underdeveloped, and vulnerable people:

> *For instance I did an interview yesterday where we interviewed a guy with a PhD and we determined that he was not fit for the project work. ... What I'm saying, what we, if you're going to put someone in that role, we wouldn't expect them to necessarily to have it but we have to make a judgment about whether we think they would cope with it.[…] (Emp 4)*

The vulnerability of EHDR graduates was explained by their preference for and exposure to university life. Industry was seen as the 'real world' and engineering academics were seen as out of touch with not just industry, but society at large:

> *Engineering is about, if you like, helping the community and to help the community, you've got to understand what the community needs and particularly if the people that are lecturing and providing guidance to the students have themselves not spent much time in industry [voice pause]; I know that [organization] has been trying to get a situation where academics have a certain mandated number of hours of industry time. (Emp 4)*

Not only was the university environment seen as removed from real life, but the employers also suspected engineering academics of being refugees from the pressures and challenges of industry who fled to the relative safety of the academic environment:

> *I think probably in chemical engineering most academics have got a small amount of industrial experience but equally I suspect most of that experience is not good for them or wasn't a good experience, which is why they return to academia. So I think the great majority would be biased against industry and would attempt to keep the students in academia. (Emp 8)*

In all, thirteen employers commented on the value of knowledge and creativity skills, and eighteen employers expressed concern about difficult personal and social attributes.

2.4 Accommodating

Accommodating creativity refers to a willingness to accept, to some extent, difficult social attributes implicitly associated with creative people in order to gain the knowledge and skills that result in creative outcomes. If an employer seeks creative skills as a means to achieving novel outcomes, the employer is more likely to accommodate some perceived problematic social attributes. This willingness to accept such a person creates a tension in the employer's decision-making process, due to the perceived risk associated with an EHDR graduate who possesses difficult characteristics.

> *So you know, if they have got the normal set of life interests, it is really great….But that is not to say that if someone came along and was absolutely brilliant and there were just a few little funnies about them, you might make, you would say, 'gee you know, they really are brilliant' and you could probably accommodate one or two unusuals per twenty-five.…But you know, you wouldn't want a whole team of them…But you are really looking, sometimes you do get someone who is quite brilliant, who is a bit unusual and you say, 'well yeah, we will take a risk here' and it ends up that they are probably going to be okay. (15D)*

Employers who seek innovative adaptors do not require an engineer with the level of creativity to produce original outcomes. These employers viewed EHDR graduates as creative, as defined by Amabile (1983), and many associated creativity with undesirable personal characteristics. It would seem likely, therefore, that these employers would be less inclined to engage an EHDR graduate, and that an EHDR qualification would hinder a graduate's chances of employment.

2.5 Employers' suggestions for solution

Suggestions for improving the employability of EHDR graduates in industry focused on the benefits of increased industry contact and influence on the HDR candidate:

- Pre-candidature industry work experience
- Shared academic/industry supervision
- Industry relevant research topics
- Joint university/industry projects
- Industry-based professional development for engineering academics

These suggestions are not new, nor do they adequately address concerns. For example, despite the anticipation that university-government-industry linked Cooperative Research Centres (CRCs) would enhance industry readiness of PhD graduates in Australia (Harman, 2004), a recent comparison of employability outcomes of PhD graduates in CRCs found remarkably few differences in post-candidature employment success between CRC and non-CRC graduates (Pitt et al. 2009). None of the employers' suggestions in the current study directly addressed their concerns about perceived troublesome personal characteristics of EHDR graduates, and thus ignored 'the elephant in the room' they revealed during their discussion about EHDR graduates' employability.

3. DISCUSSION

Employers clearly value the knowledge and creativity skills gained in engineering research training, but their willingness to engage graduates in industry work is coloured by concerns about personal characteristics that appear to reflect outmoded notions of the creative genius. It was not an assumption of this study that the aim of the research education process is to prepare workers for industry. Nevertheless, many EHDR graduates are interested in pursuing industry-based work, and the knowledge that employers maintain prejudices about personal characteristics of EHDR graduates should concern the engineering profession both within and beyond the academic environment. Along with efforts to promote generic employability attributes in EHDR graduates, this study suggests the need to actively promote an image to the larger community of creative engineering research training that dispels the myths of boffinism and mad genius.

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CAPTURING AND MONITORING OF LEARNING PROCESS THROUGH A BUSINESS PROCESS MANAGEMENT (BPM) FRAMEWORK

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Abstract: In recent years, e-Learning systems have significantly impacted the way that we learn within universities, both in providing self-learning support and flexibility of course delivery. Virtual Learning Environments (VLEs) such as Moodle help facilitate the management of educational courses for students, in particular by helping lecturers and students with course administration. However, issues still remain; in particular e-learning environments provide a *one size fits all* approach to the learning process through the course materials - each student must follow the same learning path, regardless of their *a priori* knowledge, learning requirements or learning disability. Many commercial VLEs allow course writers to build courses as groups of lessons, but it is currently not possible to monitor the learning process of individual learners or learning groups through the course material in real-time. In order to solve the issues of a *one size fits all* approach; this paper discusses the development of a system that develops an adaptive learning process management system, using the concept of Service Oriented Architecture (SOA) and Business Process Management (BPM). This system allows the course-writer to monitor the learning process of the learners in real-time and manually adapts the learning path or course materials. The paper also discusses possible future extensions to the work that would allow for the automatic adaptation of the learning path to meet an individual learner's needs. The paper concludes by discussing the benefits and limitations of our BPM implementation and discusses future extensions to allow for the automatic adaptation of learner's learning path.

Keywords: Service Oriented Architecture, Business Process Management, Business Process Execution Language, Virtual Learning Environment

1. INTRODUCTION

The ubiquitous nature of the Internet/Web has enabled e-learning to be a fundamental tool for training and development, and it has altered the availability and the way that we access our learning materials. In the academic environment, e-learning is becoming vital for distance education, and when e-learning is seen as complementary to the classroom environment it can help to strengthen the traditional pedagogy. While an education pedagogical structure is paramount in established educational systems (formal or informal), the role of technology should be seen as a platform to realising such pedagogy. Compromising education pedagogical structure due to technological deficit would be detrimental to the expected learning outcomes, even though it is arguable that technology can influence the course or shape of such pedagogy. Modelling traditional and distance education pedagogical structure can be challenging because of the variety of choice of appropriate technologies.

A Virtual Learning Environment (VLE) is a software system that helps to bring the implementation of e-learning to realisation. It is a set of teaching and learning tools designed to enhance students' learning experiences through the use of computer resources and the Internet within the learning process. VLEs were originally designed for distant participants (learners & teachers) but they are not restricted to distance education (Dillenbourg, 2000). In fact, research shows that VLEs based on Web 2.0 technologies have the potential to: stimulate active participation and individual production of knowledge; support the performance of formal and informal web-based learning activities; take the best out of the "collective intelligence" in order to create learning experiences; and, support the dynamics and openness of a learning process (Malinka, Anguelina, 2009). One of the limitations of the existing VLEs (e.g. Blackboard, Moodle etc) to drive new education approaches is that e-learning environments provide a *one size fits all* approach to the learning process through the course materials - each student must follow the same learning path, regardless of their *a priori* knowledge, learning requirements or learning disability. There is a need to extend current VLE functionality beyond this limitation if VLEs are to continue to play a significant role in the educational systems of the future.

Designing and developing a VLE that will significantly address the issues of *one size fit all* is important, therefore such a VLE needs to be designed and developed as a system where:

- It seamlessly integrates heterogeneous technologies and multiple pedagogical approaches.
- Flexible formal and informal learning flow are allowed to drive a new education approaches.
- Learners learning pathway can be tailored to their profile and dynamically adapted to their run-time behaviour.

This paper presents the technological framework to deliver a VLE system that allows customised learning paths through course materials to be created, delivered and monitored. This gives the course-writer the ability to analyse, manage and change the learning pathways in response to the monitored data. The course-writer can also manually adapt the course materials in response to monitored data.

Figure 1 illustrates an overview of the proposed VLE that allows monitoring of an adaptive learning process. It depicts how customised learning path can be created, depending on a learner's unique need. A learner logs into the VLE to work through course material, the requisition component checks for outstanding pre-requisite or special needs that might impede the learning process before any topic is displayed. Mastery level of each topic is examined and if each topic is not passed the learner is auto-routed through the path manager to additional external resources. The course-writer can login to the same system to see a dashboard, which allows for individual or aggregate learners' progress through the materials to be monitored.

2. CURRENT VIRTUAL LEARNING ENVIRONMENT SOLUTIONS

Following the emergence of the Internet, education communities have witnessed the emergence of software-aided tools that aim to support learning and teaching activities through the Internet (O'Leary, 2002). VLEs are software systems designed to facilitate teachers in the management of educational courses for their students, especially by helping teachers and learners with course administration. The principal components of a VLE package include: curriculum mapping; student tracking; online support for teachers and students; electronic communication; and, internet links to outside curriculum resources. The most popular VLEs currently available are Blackboard, WebCT, Moodle, Learning Activity Management System (LAMS), SAKAI and many others. Blackboard and WebCT are two leading commercial systems that are used worldwide. SAKAI and Moodle are open source VLEs that are increasingly popular (Weller, 2006).

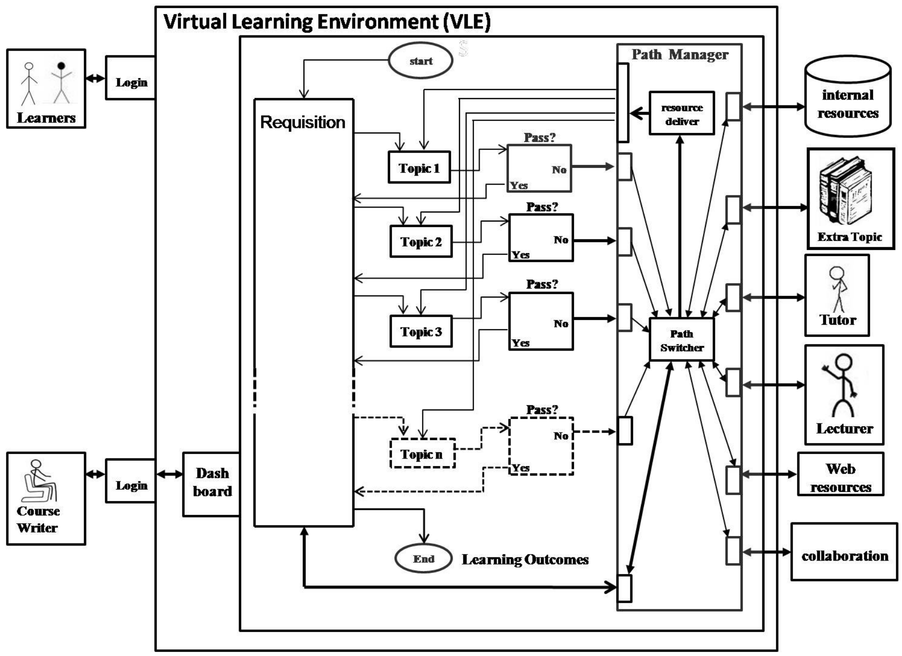


Figure 1 Adaptive learning paths being monitored and analysed by a course-writer.

2.1.1. Commercial VLEs

Commercial VLE products, which form the vast majority of VLEs in use within further and higher education, are generally characterised as 'content-centred', rather than being aimed at encouraging the active learning embodied in constructivist pedagogies (Dunn, S. 2003). The ever-increasing licensing fee is one of the factors still inhibiting the widespread adoption of commercial VLEs. Commercial VLEs are ready-made off the shelf products written externally, which offer significant initial savings in procurement and maintenance, but institutions fear future changes to the product will not be under their control. The largest market share belongs to Blackboard and WebCT, both of whom do not capture learning paths; consequently, the learning process cannot be monitored in real-time.

2.1.2. Open source VLEs

It has been argued that open-source software can help in saving the ever-increasing licensing fee of any commercial provider such as Blackboard (Wheeler, 2004). Additionally, open-source VLE open up opportunities to further develop the VLE to meet specific needs of an institution or a group of institutions. However, open source VLEs can become compromising with inadequate documentation, less functional features and numerous bugs - commercial systems are often seen as a "safer" option (Young, 2004). There is a natural affinity between the open source and academic communities, with the process of contributing code compared with that of the academic review process (Bergquist and Ljungberg, 2001). Also, many open source contributors are employed in education and many such projects begin as educational projects. For example, Moodle began as part of founder's Martin Dougiamas' Ph.D. Therefore, it would make sense that in the area of VLEs, if a successful open source solution could be found (Weller, 2006).

LAMS is an integrated system for authoring, running and monitoring Learning Designs (Dalziel 2006). It is developed using Extensible Markup Language (XML), HyperText Markup Language (HTML), Java, Flash technologies. A functioning version of LAMS was presented at the Valkenburg group meeting in February 2003, based on the "What is Greatness?" use case. At this presentation, a number of challenges for Instructional Management Systems Learning Design (IMS LD) arising from LAMS development were noted. Some of these challenges were:

- More detailed concepts of sequencing within "Acts", including within-Act multi-learner synchronisation, and Simple Sequencing
- More development of how a teacher monitors and approves actions in real-time during a complex, multi-task activity sequence." (Dalziel 2006)

LAMS is inspired by, and heavily based on IMS LD (Dalziel, J. 2003), therefore, it is inherently faced with the challenges outlined above. The "Think globally, act locally" approach is lacking within existing VLEs. Thinking globally is to define and expect the same learning outcomes through well designed course materials; however, acting locally is to expect that each learner is different and consequently requires a mechanism for each learner to uniquely meander his/her way to achieve the same learning outcomes. A single learning path for all learners in LAMS or any other VLEs is tantamount to "Think globally, act globally" i.e. every learner must act in the same way to achieve the same thing. This replicates the same issues of *one size fit all* approach. Since the learning path in LAMS is predetermined, what is left to monitor is the learning process through a sequence of learning activities. The desired "learning outcomes", without an adaptive instructional design, is reduced to the "learning". LAMS may therefore be seen as the first in a potentially extensive range of specialised learning design editors that provides easy to use high-level tools for a particular pedagogic approach. Such tools do not necessarily aspire to generating all possible pedagogic structures, but rather to providing effective solutions for the needs of practitioners (Griffiths, 2005).

The drawbacks of both the commercial and open source VLEs, when addressed with the conceptual framework of certain open source technologies, set a good foundation for the development of a future VLE. This paper presents a Business Process Management (BPM) concept as the conceptual framework for capturing and monitoring the foot print of an adaptive learning process.

3. BUSINESS PROCESS MANAGEMENT (BPM) CONCEPTS

BPM refers to: aligning processes with the organisation's strategic goals; designing and implementing process architectures; establishing process measurement systems that are aligned with organisational goals; and, educating and organising managers to manage processes effectively (Bosilj-Vuksic, *et al*, 2005). It ensures continued improvement of business performance by managing the processes and their components: organizational structure, policies, business rules, regulations, human resources, and ICT. The term is occasionally used to refer to various automation efforts such as workflow systems. BPM enables automation of business processes by separating process logic from the applications that run them; managing relationships among process participants; integrating internal and external process resources; and, monitoring process performance (Bosilj-Vuksic, *et al*, 2005). Figure 2 illustrates the life cycle of a BPM system right from the inception of a business concept. A business concept is: model in a business modeller; implemented and deployed in a business run-time engine; monitored in a business monitoring activity system (e.g.

dashboard); and, analysis/optimisation is performed based on feedback for continuous improvements.

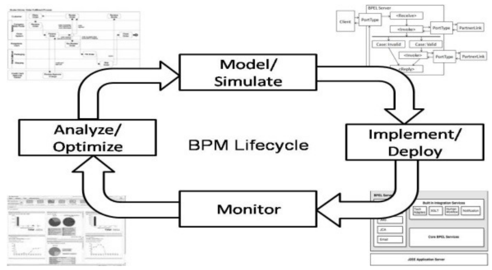


Figure 2 End-to-end life cycle of BPM

3.1. BPM-based VLE

The choice of technological model of any VLE can potentially determine the extent to which such a VLE can best serve to implement any educational pedagogy. However, the ability to capture and monitor an adaptive learning path within an adaptive workflow management system would require a much more advanced technology. For the orchestration of any flexible and adaptive learning process, BPM technologies would be *sine qua non* to its implementation in the 21st century because BPM technologies are the official standards for any workflow management system. Workflow to this point has always been about software, computer or machine interactions, but BPM helps to introduce human interaction into a workflow model. This is one of the greatest advantages of BPM as human intervention is routinely expected in implementing a hands-on adaptive learning process. This paper employs and explores the particular BPM technologies that enable the automation and monitoring the foot print of an adaptive learning process.

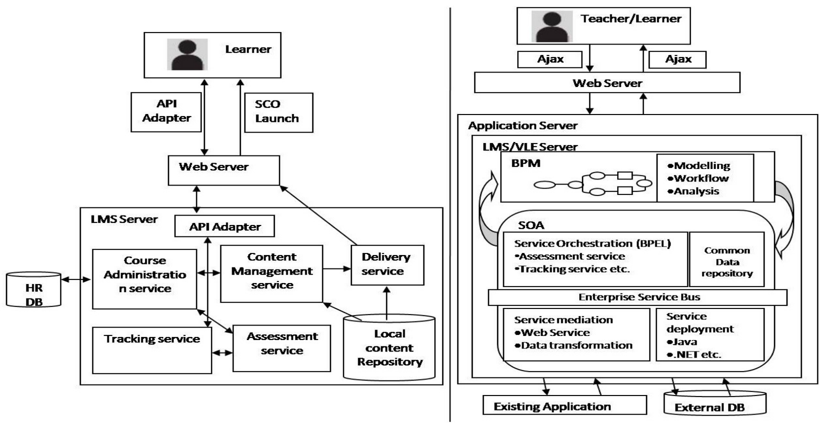
3.2. BPM Technologies for Learning Process managements

BPM technologies are employed to implement the learning processes through course materials by orchestrating interactions between learning services (learning activities and learning objects exposed as a web services) within the proposed BPM-based VLE. The paper focuses on the use of the following popular BPM technologies;

- Business Process Modelling Notation (BPMN) – This is a core enabler of BPM. BPMN is a standardised graphical notation for drawing/modelling business processes in a workflow system. BPMN has been developed to enable a business user to develop readily understandable graphical representations of business processes. In the proposed BPM-based VLE, BPMN is used to model learning processes/activities. The course-writer would in effect chart the available paths through the course material and would describe each interaction with the course material/tutors etc.
- Business Process Execution Language (BPEL) – BPEL allows composition of web services and it is therefore the top-down approach to Service Oriented Architecture (SOA). It's a language that specifies the behavior of business processes (modeled in BPMN) between Web services and as Web services. It is expressed in XML file that can be read and executed by any conformant BPEL engine. In effect this technology would allow the BPMN chart that is created by the course-tutor to be 'compiled' into the software system that forms the learning part of the VLE.

Service-oriented Architecture (SOA) is an architectural concept that relies on loosely-coupled software agents to perform specified tasks. Although SOA is not a BPM technology, both technological concepts are complementary. Web services are the primary technology for implementing SOAs, composition of Web services is needed to realise the vision of SOAs. BPEL is the primary industry standard for composing Web services (service can be implemented in any language). Learning activities, learning objects and external recourses are exposed as web services; these in turn are orchestrated using BPEL. The recent release of open-source systems like JBoss jBPM, Intalio, Spagic etc have made traditionally expensive BPM tools available to the academic community. This makes business process orchestration faster, cheaper and monitoring the execution of the business processes so that managers can analyse and change the business process in response to monitored data.

4. IMPLEMENTATION



(a) (b)

Figure 3 (a) An illustration of a SCORM compliant VLE model (b) An illustration of the proposed BPM-based VLE**.**

Figure 3(a), illustrates a Sharable Content Object Reference Model (SCORM) compliant VLE model**.** Figure 3(b) illustrates the proposed BPM-Based VLE architecture diagram. Because BPEL is a web services orchestration language, all learning components (Modules, learning stage, learning requisition, topics, questions, marking questions, mastery level etc.) are exposed as web services.

4.1. Mapping a Learning Process with BPMN

BPM technologies are an important part of the implementation of an adaptive leaning process that can be monitored. In this paper the Eclipse BPMN Modeller is used because it allows all stakeholders to get involved in contributing to how the future learning process should take shape. IT specialists may or may not even surface at this stage, as the analysis of a learning process in the BPMN diagram as shown Figure 4 is a process-oriented architecture. In the BPMN diagram (expanded in Figure 5a-e below), blue components indicate learning components invoked; white components indicate the internal states of the process and the gold components indicate the human (learner) involvement/task.

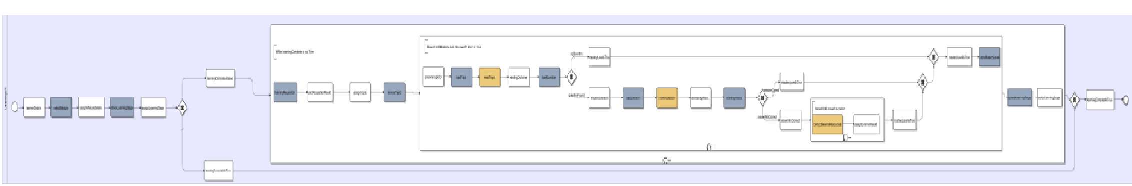


Figure 4 BPMN diagram of a Learning Process

The segments of the BPMN diagram are further explained in Figure 5(a)-(g).

Figure 5(a) Learner's details associated with a module and learning stage.

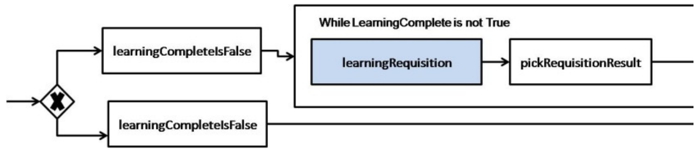


Figure 5(b) If learning is not complete, request for learning is made on learner's behalf.

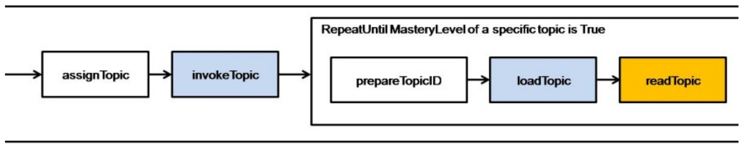


Figure 5(c) Learner revived a topic until a mastery level is attained on the topic.

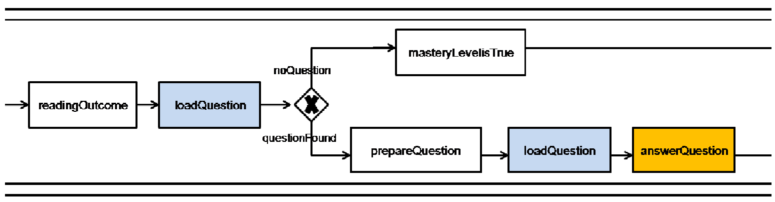


Figure 5(d) Mastery level is tested through available questions for the topic.

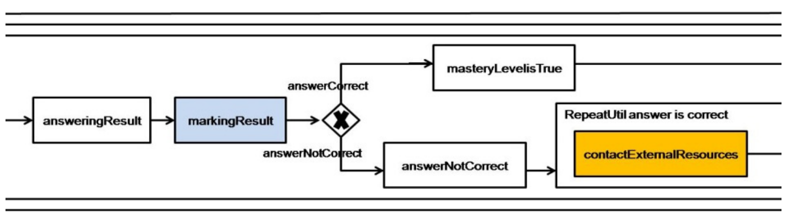


Figure 5(e) If a learner struggles over a question the learner is routed to external supports.

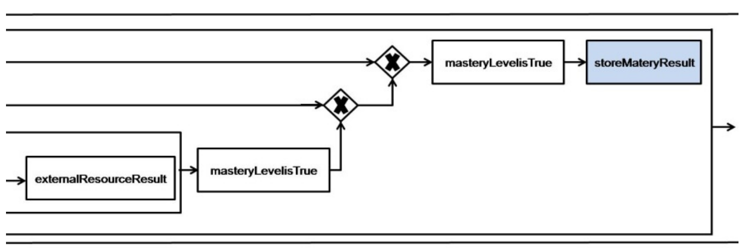


Figure 5(f) Once the mastery level is achieved the system maintains the mastery level.

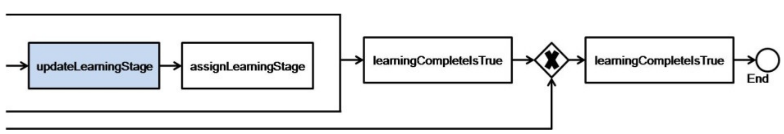


Figure 5(g) The system loops through until all topics have been completed.

4.2. Transforming Learning Process BPMN to Executable Learning Process BPEL

BPMN diagram is not executable hence the need to transform into an executable program language. In this paper the BPMN diagram in Figure 5 is transformed into BPEL. Using Eclipse SOA Tool Platform (STP) Intermediate Model (IM), the initial step involves exporting the BPMN to the IM (a "bridge" between STP editors). A half completed BPEL process is generated from the IM and the BPEL is completed with all necessary coding and the artefacts (e.g. deployment descriptor, the BPEL web services interface etc.) needed for deployment. Figure 6 shows a fragmented diagram of the generated BPEL version of the BPMN diagram in Figure 5. The completed learning process BPEL and all its artefacts are deployed into a BPEL engine where it can be accessed by any BPEL client.

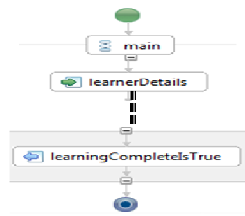


Figure 6 Fragmented BPEL version of BPMN Learning Process

4.3. Monitoring Learning Path on a Dashboard Console

While capturing the learning process is accomplished within the BPEL engine where the BPEL is running, monitoring the stages of the process when invoked by a client requires a BPM dashbaord/Business Activity Monitoring (BAM). BAM is the marriage between business integration and business intelligence. BAM provides real-time alerts based on business metrics when business processes are in need of intervention. The open-source Spagic BPM dashboard is used to monitor the deployed BPEL learning process and Figure 7 shows the chain of the deployed learning process in a BPM dashboard. Figure 8(a) shows the learning path a learner maintained to complete a learning process. Figure 8(b) shows a learner stuck at a particular stage of the learning process and this is where an internention is probably required.

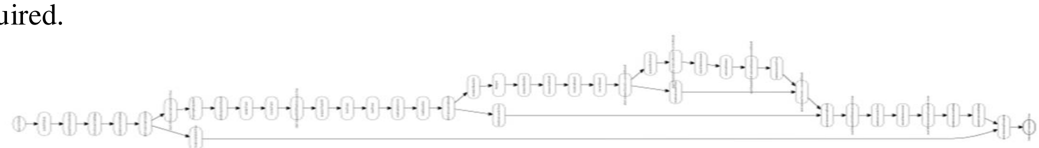


Figure 7 Chain of an un-invoked learning process.

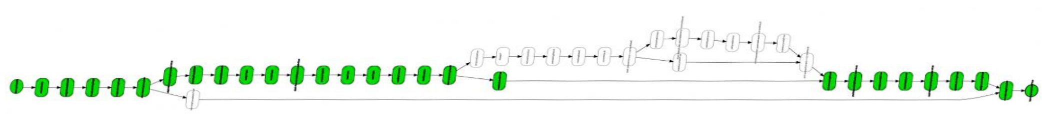


Figure 8(a) Learning path of an advancing learner captured and monitored.

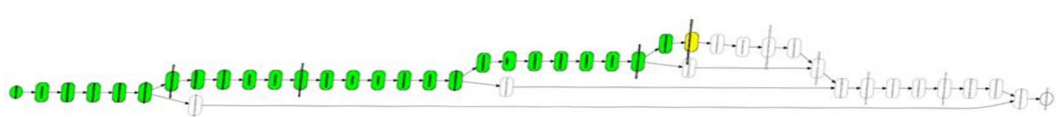


Figure 8(b) Learning path of a struggling learner captured and monitored.

5. CONCLUSION AND FUTURE WORKS

In this paper we have presented an approach to modelling, analysing, detecting and monitoring a learning process through course materials. We model and analyse the learning process in BPMN, execute semantic web services (learning activities, learning objects and external resources) orchestration with BPEL and using Spagic BPM dashboard we were able to monitor the learning process in a real-time manner. Within our approach however, are a number of assumptions. In the first case we have abstracted several areas of the composition such as learners' prior knowledge, learning requirements or learning disability. Secondly, the BPEL modelling structure for learning material is hardcoded, but needs to be generated on-the-fly to accommodate any structure of course material. We have proposed an initial architecture, but future work will aim to provide a comprehensive and extensible workflow solution to the *one size fit all* problem by extending the BPEL4People, XForms technologies. These will also include full implementation of all areas of assumptions so as to create a more flexible and adaptive learning path in the learning process.

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CRITICAL THINKING IN THE UNIVERSITY CURRICULUM

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Abstract: This paper describes a multi-qualitative study undertaken to examine the issue of critical thinking as a graduate attribute. Critical thinking is a graduate attribute that many courses claim to produce in students. However, it is important to understand how academics define and describe critical thinking and whether their understandings of critical thinking differ, depending on their discipline or subject area.

The paper describes a series of in-depth, semi-structured interviews with academics involved in teaching and learning in a number of disciplines, including engineering. The objective of these interviews is to look at how different disciplines define critical thinking and how they teach critical thinking in their courses. In addition the paper describes how a selection of modules particularly concerned with the acquisition and development of critical thinking will be chosen, and the interviews that will be carried out with module coordinators about the module design and assessment, recognition and measurement of critical thinking.

Keywords; symposium, engineering education, transformation, unsustainable, society, international.

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1. INTRODUCTION

There is currently considerable interest in the generic attributes of graduates (Jones 2009), particularly critical thinking, and considerable discussion about the precise meaning of the term (Barrie 2006, Jones 2007). There has, however, been relatively little investigation into the relationship between disciplines or subject areas and the concept of critical thinking (Jones 2007, 2009) and how it is realised and recognised through curriculum and pedagogy (Jones 2009, Maton 2009). This study attempts to rectify this by embarking on a large-scale examination of the views and perspectives of academics, students and employers regarding critical thinking and its importance.

Given the increasing emphasis on the ability of universities to clarify the nature of the education they provide and the contribution of their graduates to society, it is important that they can describe the quality of their graduates in ways that are meaningful to a wide range of stakeholders, including employers, professional groups and policy makers (Barrie 2006). However, in order to avoid decontextualising attributes such as critical thinking, it is important that they are understood within specific disciplinary or subject contexts and that academics have a shared understanding of the concept and of the teaching and learning strategies that support its acquisition. It is also important that students understand what is expected of them in relation to graduate attributes such as critical thinking and that assessment strategies are designed to determine the degree to which it has been acquired. In addition, it is extremely important in the given economic climate to understand how employers view critical thinking and if there is some cohesion between what universities strive to produce in their graduates and what employers want to see.

This paper describes a study currently being carried out that strives to examine how critical thinking is viewed by academics and how it is instilled in students, how it is understood by students and whether they have achieved some level of critical thinking in their time at university and how employers view and rate critical thinking as a gradate attribute. The study is still taking place and therefore this paper will describe the methodology employed and initial, preliminary findings.

The aim of this study is to explore the understanding and realisations of critical thinking in the university curriculum and in the world outside university. The objectives are as follows:

- To discover what are the understanding and views held by academics in variety of disciplines regarding critical thinking as a graduate attribute.
- To find out if academics' understanding of critical thinking is influenced by their own discipline and to assess if there are differences between disciplines in how they view critical thinking and rate its importance.
- To examine if critical thinking is built into university curricula and modules and if it is possible to in some way measure the achievement of critical thinking in university students.
- Finally, to examine how the world outside university, in the form of employers, understand, define and rate critical thinking. Do employers want critical thinkers and are universities producing the graduates that employers require?

2. METHODOLGOY

2. 1 Introduction

The study has been designed to comprise of several layers. It is a qualitative study where a number of in-depth, unstructured interviews have been and will be carried out with academics and employers. This work will be supplemented by a documentary analysis of students' work.

There are a number of steps to the work, as set out in Table 1. Each step will now be described.

Methodology:
Step 1: Contact with Heads of School and interviews with their nominees about critical thinking in different disciplines
Step 2: Analysis of modules and module descriptors Documentary analysis of the work of students in related module descriptors
Step 4: Interviews with employers

Table 1 Methodology employed

2.2 Interviews with academics regarding critical thinking

A major objective of this study was to discover what are the understanding and views held by academics in variety of disciplines regarding critical thinking as a graduate attribute. Therefore, a series of semi-structured interviews was carried out with academics from a range of disciplines in order to determine how they defined critical thinking, to gain understanding of critical thinking both as a generic and a discipline or subject based attribute. The sampling was purposive and snowball, access to all participants and documentary materials was negotiated first through Heads of School and then their nominees.

The following disciplines were selected:

Discipline	Arts/Science	Professional – Y/N
Chemistry	Science	N
Agricultural Science	Science	N
Mathematical Sciences	Science	N
Architecture and Civil Engineering	Science	Y
Physics	Science	N
Mechanical Engineering	Science	Y
Economics	Arts	N
Sociology	Arts	N
Social Justice	Arts	N
Business	Arts	N
History	Arts	N
English	Arts	N
Law	Arts	Y

Table 2 Academics interviewed

These were selected to reflect both professional and non-professional disciplines and also to ensure that we had a range of science-based and arts-based disciplines. It was felt that this selection would give a wide range of view points and would allow us to compare the differences and similarities between disciplines with regard to critical thinking.

For each of these disciplines, the head of the school in which that discipline was located was contacted and asked to nominate a person from within their school who would be willing to speak to us about critical thinking and who had an interest in developing teaching and learning within that school. The nominees were then contacted and asked if they would be willing to act as a representative of their discipline to discuss their understandings of critical thinking as both a generic and discipline specific attribute.

Interviews were conducted in March and April of this year and were in-depth and semi-structured. The interviews have lasted approximately one hour in each case and in those interviews academics were asked about how they defined critical thinking, in particular in relation to their own discipline. In addition, the participants were asked to set out how their views tied in with the views of others in their discipline and if they thought others in their discipline were aware of definitions and concepts surrounding critical thinking.

Interviewees were then asked about whether they felt that critical thinking was important for their graduates and how it ranked when compared to the other skills that they might require to be competent graduates.

Interviewees were ask to consider if they felt students became critical thinkers when in the university and how they ensured that happened in their courses. They were asked to consider if critical thinking was addressed explicitly in the curriculum and if module learning outcomes really addressed the issue of critical thinking. They were also asked how they assessed and measured critical thinking, and if they felt that it was really possible to assess and measure critical thinking realistically.

Finally, interviewees were asked about the students on their course and whether they felt those students were aware of what critical thinking was. Were students made aware of definitions of critical thinking and did the students, in their view, hold it to be an important attribute.

At the end of the interview, interviewees were asked to nominate one or two modules which demonstrated critical thinking being developed in students.

Some interviews have already taken place and all will be completed by the

2.3 Analysis of modules descriptors

The next stage of this project will commence in April for those interviews that have taken place and will be completed by the end of this summer. Documentary sampling is of 2 module descriptors nominated by each module co-ordinators, their associated assessment tasks, any other relevant module materials the co-ordinator wishes to provide and the anonymised responses of 3 students to the module's assessment tasks (one from each of the upper, middle and lower achievement ranges). Once selected by the module co-ordinator as falling into the upper, middle or lower ranges of achievement on these tasks, 3 students per module will be invited to consent to their anonymised responses to the assessment tasks being made available for the researchers.

Selected module descriptors and their associated assessment tasks will be analysed in order to ascertain whether and to what extent critical thinking is made explicit as a learning outcome. We will look at the module descriptors that are linked to each of these modules to examine their learning outcomes, assessment tasks and teaching methods used to achieve those learning outcomes. We will be looking to see first of all if the learning outcomes specifically mention critical thinking or if critically thinking is addressed in a more implicit manner in the learning objectives. We will then go on to look at what the module coordinator uses to try to instil critical thinking in the students. What methods are used that develop critical thinking? Are any innovative approaches used? Do these differ in different disciplines? How dependent are these on how the discipline both defines and rates critical thinking?

We will also be very interested to examine how a particular module checks if students actually have developed critical thinking in the module. How is critical thinking recognised in a student and what methods are being used across the university to try to measure critical thinking in students? With this in mind, we will look at how the development of critical thinking ability may be demonstrated in students' work and to this end we will ask module co-ordinators to nominate 3 pieces of students' work for the purposes of documentary analysis. We will work with de-identified copies of this work and will seek the explicit written consent of the students nominated through the module co-ordinators.

At the same time, we will also conduct interviews with the module coordinators to contextualise our documentary analysis. This interview ill focus on how students develop critical thinking abilities and how the module coordinator sees this as being represented in their module.

2.4 Interviews with Employers

The final stage of this project will take place next year. The researchers involved in this study are from a number of diverse backgrounds: Health Sciences, Education and Civil Engineering. It in intended at this point to contact employers in each of these disciplines and to carry out semi-structured interviews looking at how they view critical thinking as a graduate attribute, if it is important, how they define it and if the graduates from Irish universities demonstrate what they see to be critical thinking.

3. ANALYSIS AND CONCLUSIONS

The study is a multi-method qualitative study, involving in-depth, semi-structured interviewing (Fontana & Frey 2003) together with documentary analysis (Prior 2003). Analysis and interpretation will be informed by the work of Silverman (2003) on interview, narrative and content analysis, Prior (2003) on documentary analysis and Attrride-Stirling (2001) on thematic network analysis.

It is hoped that this work will inform research into critical thinking in the university curriculum. While critical thinking is often stated to be very important to graduates, the definitions of what critical thinking really is are confused and diverse. Do all disciplines see critical thinking as the same? Our earlier analysis of interviews conducted so far would suggest not, with significant differences between disciplines in a number of areas. Disciplines differ firstly in how they interpret and define critical thinking, with some disciplines having a very clear idea of what critical thinking is and where it comes from. For other disciplines, the issues of critical thinking was felt to be very important but the definitions held by that discipline of critical thinking were not very clear and there was no real single defition agreed by that discipline of critical thinking. Diciplines were also very different about how they felt that critical thiking could be assessed and taught. Some disciplines were keen to build critical thinking into their modules from an early stage, even if they did not call it critical thinking. But they asked students to develop analysis skills, research skills and skills of independent learning very early on and built these into the curriculum. They used diverse assessment techniques (work placement, theses, research projects, group projects) to try to assess if students had developed these skills. Other disciplines saw critical thiking as being less important and not something that needed to be measured.

Assessment of Educational Objectives in Chemical and Petroleum Engineering Programs

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Abstract: Within the Chemical and Petroleum Engineering (CPE) programs, establishing and reviewing educational objectives is part of the assessment and continuous improvement cycle for the programs. This paper describes a process for the establishment and assessment of the educational objectives set by the CPE Department at the United Arab Emirates University. This process is initiated by defining the CPE programs outcomes to match the ABET (A-K) EC2000 criteria and from these outcomes the program educational objectives are derived. Next, the assessment tools are defined and these include Alumni and Employer surveys and special formats are prepared to achieve this purpose. The Alumni Survey is designed to provide the information needed by both programs to continuously measure the degree to which the concluded educational objectives are attained. The Employer Survey is designed to assess how well the graduates of the two programs meet the educational objectives from their employers' perspectives. The results of the two surveys are averaged using a weighting factor designed to provide some judgment on the importance, quality, and number of feedbacks of each tool. It may generally be concluded that the overall educational objectives of both programs have been largely met with average score for each objective between 4 and 4.4 out of 5.0 and that incremental enhancements could help achieve further improvements.

Keywords: symposium, engineering education, program objectives, assessments

1. INTRODUCTION

The Accreditation Board for Engineering and Technology (ABET) is a professional accrediting organization in USA that accredits engineering, technology, computing and information science, and engineering related programs in the United States and internationally (Petrova et al., 2006). The objectives of ABET accreditation are to serve the public, industry, and the profession by stimulating the development of improved engineering education, encouraging new and innovative approaches to engineering education, and assuring that graduates of an accredited program are adequately prepared to enter and continue the practice of engineering. The new developed criteria of ABET for accrediting engineering programs EC 2000 (A2K) have changed the way that engineering programs prepare their graduates (Bai and Pigott, 2004). In order to survive in the future, each program has to develop a strategy to meet the new requirements specified in the EC2000 (A2K).

The philosophy of EC 2000 is to allow institutions and engineering programs to uniquely define their mission and objectives to meet the needs of their constituents. In addition, the new ABET system focuses on continuous improvement of program based on the results of the assessment process for program objectives and outcomes and on the input of constituents (Whiteman, 2003).

The CPE programs at the United Arab Emirates University were established in 1980. The mission of these programs is to meet the educational, research, and service needs of UAE society by providing programs and services of the highest quality. Also it contributes to the expansion of

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knowledge by conducting quality research and by developing and applying modern engineering tools and techniques that could play a significant role in the technical and economic development of the country. The CPE programs' educational objectives were designed to meet the UAEU mission and to fulfill the ABET requirements. These objectives were intended to serve new graduates by providing them with:

- Adequate skills including, understanding of scientific and engineering concepts, effective oral and written communication, ability to participate in life-long learning, diverse and global professional careers, project management and decision making.
- Strong foundation in engineering principles and practices, based on the learning of fundamentals of engineering, ability to use advanced techniques, and participation in relevant engineering interactions.
- Enhanced problem-solving skills that involve designing and conducting experiments, analyzing and interpreting laboratory as well as field data, innovation and conceptual thinking, and applying engineering through research and/or industrially oriented projects.
- Ability to understand important issues, such as knowledge and appreciation of the codes of ethics, awareness and appreciation for health, safety and environmental issues, integrating ethical, social, health, safety, and environmental issues into practical projects, economic evaluation and risk assessment, awareness of international standards and specifications.
- Working skills in multi-disciplinary teams; functioning with peers from other disciplines, integrating information and data from multiple sources, participating in technical seminars and industrial/professional functions and events, and adaptability to different working environments.

This paper describes a process for the establishment and assessment of the educational objectives set by the CPE Department at the United Arab Emirates University. This process is initiated by defining the CPE programs outcomes to match the ABET (A-K) EC2000 criteria and from these outcomes the program educational objectives are derived. Next, the assessment tools are defined and these include Alumni and Employer surveys and special formats are prepared to achieve this purpose.

2. PROGRAM CONSTITUENCIES

The CHME and PETE Programs educational objectives stated above must be based on the needs of the program's various constituencies. The College of Engineering, the Chemical and Petroleum Engineering Programs have identified seven constituencies.

2.1 Internal Constituencies

1. Students: the UAE University has dedicated the eight goals of its 1998-2008 strategic plans to provide high-quality education to students. Student feedback thus is very important and is conveyed to the chemical and petroleum-engineering programs through a variety of assessment tools.
2. Alumni: alumni are a resource to the programs providing feedback on its competitiveness with other chemical and petroleum engineering programs, in the U.A.E. and abroad. They keep in touch with the faculty during the department open house activities or they meet them at the Abu Dhabi Petroleum Exhibition and Conference (ADIPEC), which is held every two years, and in meetings of the Abu Dhabi or Dubai chapters of SPE.
3. Faculty: being responsible for delivering the skills, knowledge, and competencies to students, the relevant university faculty and particularly the CHME and PETE faculty members are directly involved in the educational process.
4. University Administration: being responsible on behalf of the government and the public to provide the high-quality education in the different University programs, the University

administration is an important constituency to the CHME and PETE programs.

2.2 External Constituencies

1. Employers: petroleum and chemical companies that hire the CHME and PETE graduates have certain needs in skills and competencies of graduates from the UAEU.
2. Industrial Advisory Board (IAB): in October 2003 the College has formed an Industrial Advisory Board composed of several key managers in different petroleum and engineering companies, and government authorities. They are charged with providing advice to the College programs in light of their experience and company needs. They are considered a constituency because they represent a cross section of leading companies that hires the CHME and PETE graduates.
3. Industrial Training Supervisors: the internship program for students in the College of engineering is carried out over a full semester with each student trainee supervised by a faculty member and a company supervisor. Thus, the internship supervisors are directly involved in the students' education and also the evaluation of their skills at the junior level, thereby making Internship Supervisors a valuable constituency.

In addition to these seven constituencies, the CHME and PETE programs get valuable advice and feedback from the Academic Advisory Board (AAB), formed in 2001 from leading U.S. academicians with one representative for each program. The AAB has last reviewed the engineering programs Assessment and Continuous Improvement plans in March/April 2008 and provided valuable feedback.

3. PROCESS FOR ESTABLISHING PROGRAM OBJECTIVES

In this work the CHME and PETE programs educational objectives were revised to become more consistent with EC-2000 criteria and to meet the constituencies' needs. The process was initiated by reviewing the current program objectives, fine tuned them in an attempt to generally provide high-quality education, research, and service (the three pillars of the university), and finally came up with the revised educational objectives. These new program objectives are intended to serve new graduates as well as graduates after three years of graduation. The adjusted PEO's are shown in Table 1.

Within the Department of Chemical and Petroleum Engineering, establishing and reviewing educational objectives is part of the assessment and continuous improvement cycle for the CHME and PETE programs, the elements of which are shown in the block diagram in Figure 1. The process started by defining the program outcomes to match the (A-K) EC-2000 criteria, since program outcomes are the most important part of the educational process and must foster attainment of program educational objectives. Thus, from the program outcomes, the program educational objectives are defined so that they encompass the program outcomes.

Next, the assessment tools were defined. Currently, the CHME and PETE programs have defined and used the following assessment tools.

- Alumni Survey: It is designed to provide the information needed by the Chemical & Petroleum Engineering Department to continuously measure the degree to which the concluded educational program objectives are attained.
- Employer Survey: This survey is conducted to assess how well the department graduates meet the educational program objectives from their employers' perspectives.

Results of these surveys were considered in conjunction with discussions of the Open House meetings.

Table 1: Program Objectives for Chemical and Petroleum Engineering

Objective	Chemical Eng. Program	Petroleum Eng. Program
1.	Produce graduates who possess a working knowledge of mathematics, science and chemical engineering fundamentals, and have the ability to integrate these disciplines to function as competent chemical engineers	Produce graduates with a broad knowledge of petroleum engineering and their applications.
2.	Produce graduates who are capable of utilizing principles and techniques from engineering, science, engineering planning & project management, and the natural & social sciences to develop and evaluate alternative design solutions to engineering problems with specific constraints	Produce graduates with the knowledge and critical thinking skills required to design and analyze petroleum engineering problems, taking into account, safety, environmental and societal impacts.
3.	Produce graduates with a broad enough base that they may pursue graduate studies if they choose, and be ready to pursue a successful professional career in traditional and new areas such as biochemical, pharmaceutical, food processing, polymers, environmental protection, nanotechnology, and advanced materials areas, or as managers in business, governmental careers, and engineering consultants.	Produce graduates who are effective communicators with the ability to convey and acquire technical ideas, information, and recommendations in a multi-disciplinary environment.
4.	Produce graduates who exercise professional responsibility and sensitivity to a broad range of societal concerns, such as ethical, environmental, economic, regulatory, and global issues.	Produce graduates who have been exposed to current and emerging technologies, and have the ability to pursue life-long learning through continuing education or post-graduate education.
5.	Produce graduates who work effectively in a team environment, communicate well, and are aware of the necessity for personal and professional growth.	Produce graduates with appreciation for the value of continuing professional development in maintaining their professional competence, through participation and leadership in professional organizations such as the SPE.
6.		Produce graduates who are exposed to professional ethics and who have a commitment to public welfare and the environment.

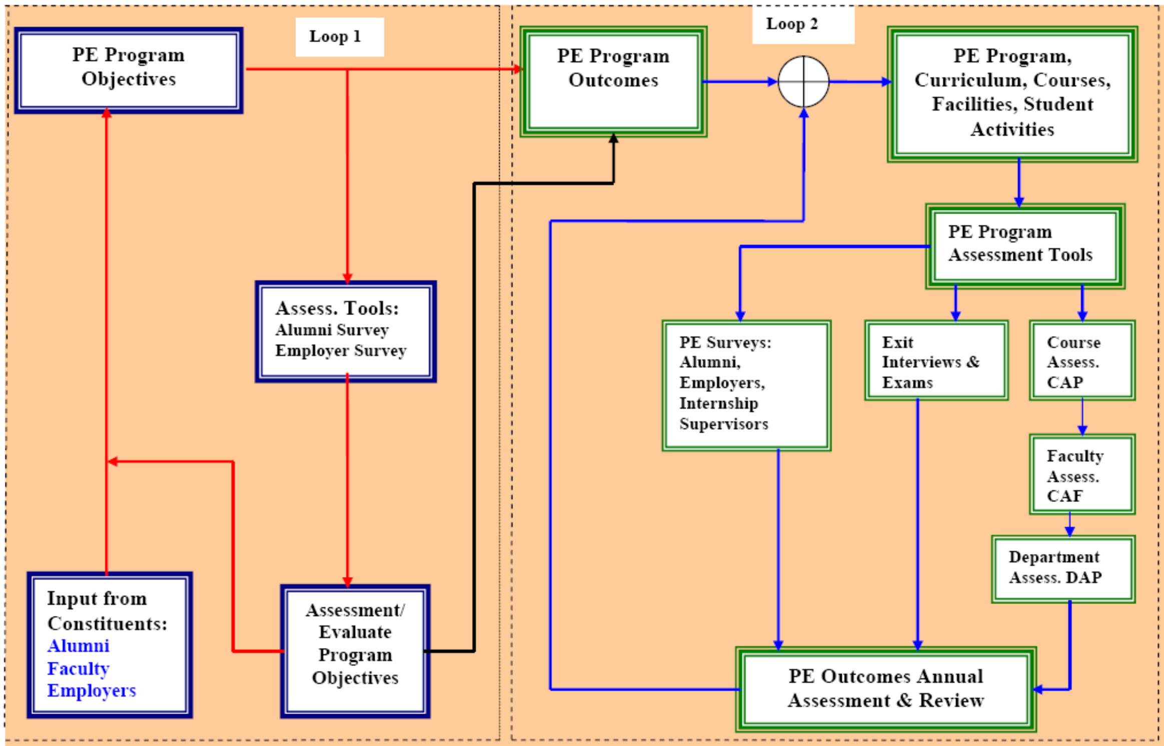

Fig. 1: PETE Assessment Outcomes and Objectives Framework

4. ACHIEVEMENT OF EDUCATIONAL OBJECTIVES

The CHME and PETE Programs educational objectives were evaluated through the assessment of two surveys, namely, the alumni survey and the employer survey. These surveys were gathered from the first and second "Open House" feedbacks which were arranged by the Chemical & Petroleum Engineering Department and held in Al-Ain in April 2007 and April 2008, respectively, and also from electronically gathered responses.

4.1 Overall Performance Index for Educational Objectives

To get a better picture of performance, the two assessment tools that were conducted to evaluate the CHME and PETE programs objectives were averaged using a weighting factor designed to provide some judgment on the importance, quality, and number of feedbacks of each tool and as follows.

Assessment Tool	Importance level	Weight %
Employer survey	External Evaluator, highly important.	50
Alumni Survey	Equally Important, engineers take the survey very seriously.	50

The results of alumni survey for year 2008 are shown in Figures 2 and 3 for Petroleum and Chemical programs, respectively. While the results of the employer survey in the same year are presented in Figure 4 and 5..

4.2 Overall assessment

The overall assessment of PETE and CHME Programs Educational Objectives based on the above two surveys are illustrated in Figure 6 and 7, respectively, showing the weighted average score for each objective. From this one can generally conclude that the overall educational objectives of the PETE program have been largely achieved with average assessment results for each objective between 4 and 4.4 out of 5.0. On the other hand, the overall educational objectives of the CHME program have largely been achieved with average assessment results for each objective between 3.83 and 4.14 out of 5.0. Thus, the CHME and PETE program have satisfied all of its educational objectives, and incremental enhancements could help achieve further improvements.

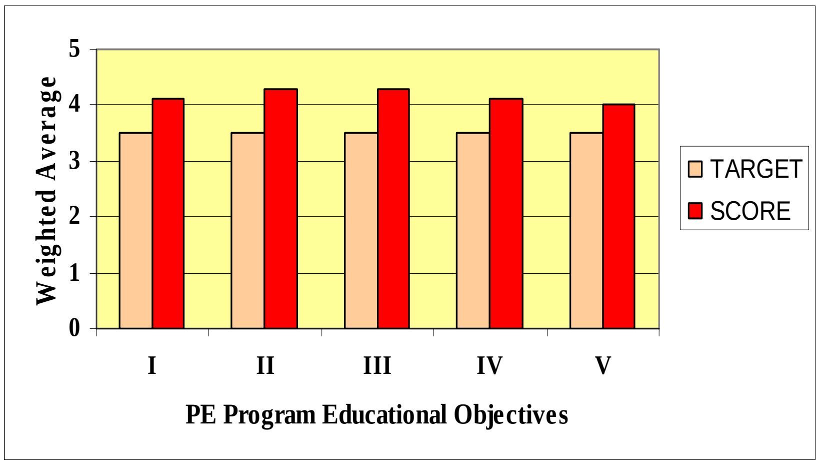

Fig. 2: Results of Alumni Survey (PETE); year 2008

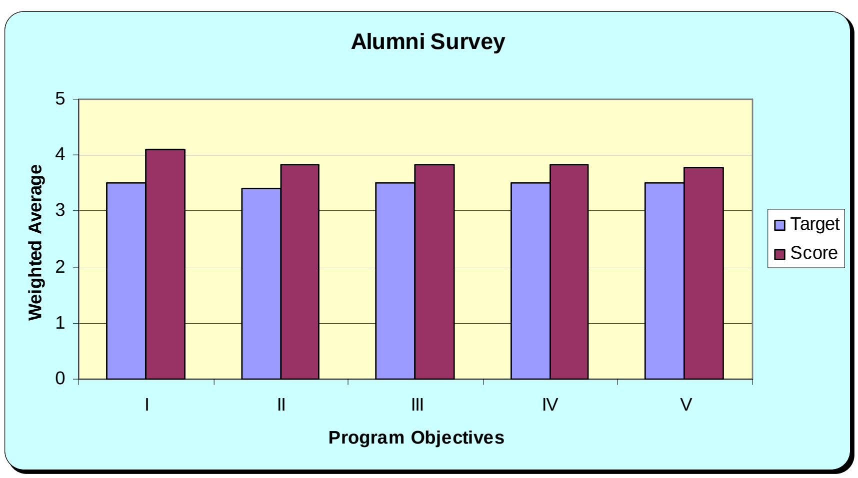

Fig. 3: Results of Alumni Survey (CHME); year 2008

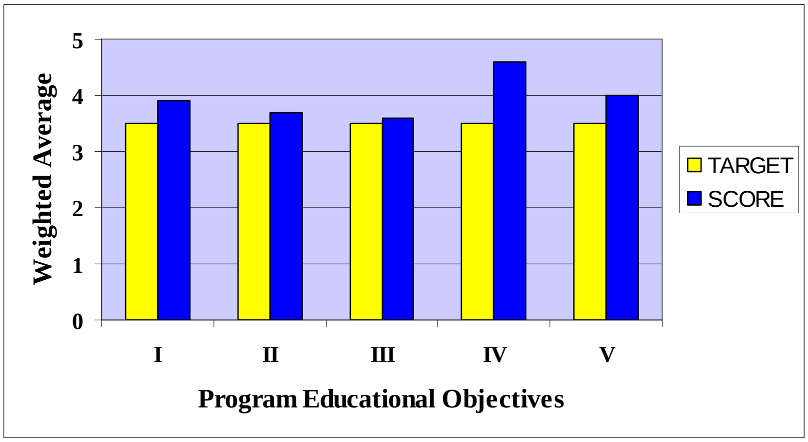

Fig. 4: Results of Employer Survey (PETE); year 2008

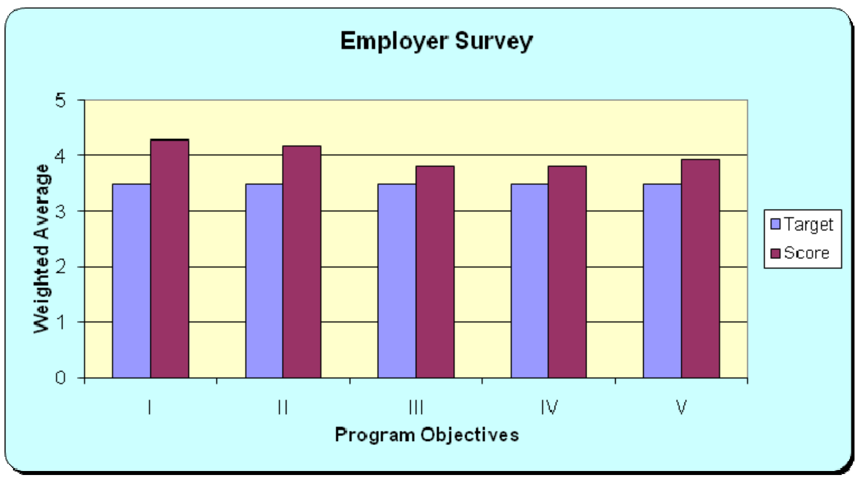

Fig. 5: Results of Employer Survey (CHME); year 2008

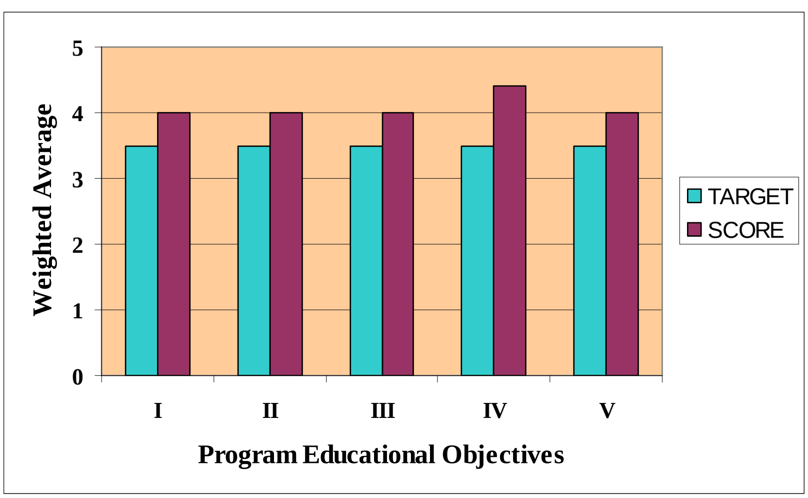

Fig. 6: Summary of PETE Program Objectives' Assessment, year 2008

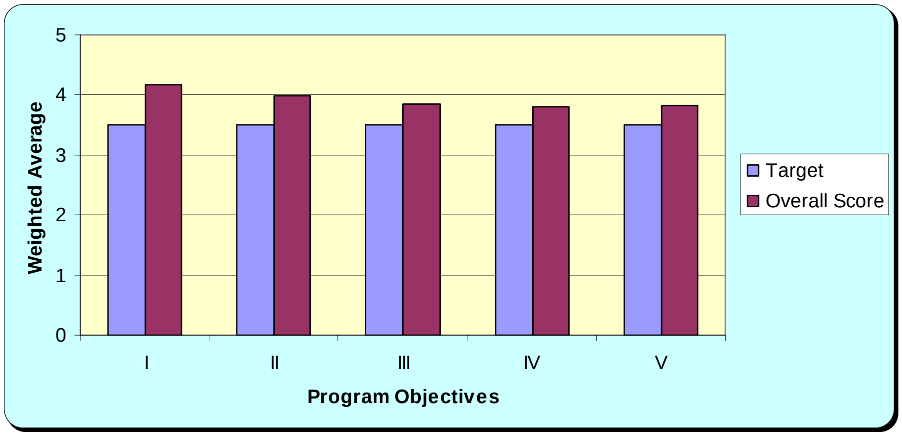

Fig. 7: Summary of CHME Program Objectives' Assessment, year 2008

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CROSS-DEPARTMENTAL INITIATIVES FOR A GLOBAL DIMENSION IN ENGINEERING EDUCATION

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Abstract: At Imperial College London the Faculty of Engineering has initiated a number of cross-departmental schemes to help support the broader, inter-professional and skills-focussed development of engineering students, and further place engineering in the context of societal priorities. In this paper, an overview of the cross-departmental schemes is given. The central coordination of the schemes, but in close correspondence with departmental teaching and learning directors, has helped instigate the developments and promote a culture of shared responsibility for engineering education which goes beyond the usual departmental boundaries. A description of the coordination effort, and subsequent mechanisms for promoting strategic educational development, is also given. Examples will be presented to demonstrate the range of learning outcomes which can be achieved through such cross-departmental approaches, such as interdisciplinary communication, real-world engineering experiences, wider technical, social and ethical awareness, and both core engineering and engineering-in-context recognition. Specific schemes to be presented include: the *Engineering Impact* series of lectures; flexible timetabling for shared option courses across departments; a common framework for engineering ethics engagement; creative design approaches; and the set-up of a new academic role for the support of student-led projects.

Keywords; global engineer; cross-departmental engineering education; professional and transferable skills; student-led projects.

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1. INTRODUCTION

Issues of sustainable development, globalisation and poverty reduction have led to much discussion on the changing role of the engineer and, subsequently, engineering education. Within the UK, there is increasing acknowledgement of the need for a *global dimension* in engineering education to address current and future economic, social and environmental challenges; see for example the survey of Bourn and Neal (2008). Many employers themselves are driving such a need through their efforts to create corporate social responsibility programmes and to attract and develop graduates who have an astute global awareness. This global awareness may include: a systems (holistic) understanding and approach to dealing with the complexities of sustainable production, process and infrastructure design, and utility provision (Fenner et al., 2006; Pritchard and Baillie, 2006); training on the skills necessary to actively engage in and contribute to multidisciplinary and international communities (see e.g. Leitch, 2006; Fallows and Steven, 2000); an understanding of the social and ethical responsibilities of the engineer to meet, for example, human needs whilst minimising resource use (De Graaf and Ravesteijn, 2001; Fenner et al., 2006); a focus on engineering development and design for basal rather than luxury human needs; and an understanding and valuing the natural environments and the interconnectedness of local and global ecosystems. At Imperial College London, it is also observed that students are drivers of this global dimension, i.e. a growing number of projects created by students to tackle specific techno-socio problems in communities in developing countries.

A global dimension in engineering education is seems a natural evolution of the profession in the age of digital communications, given an economically expansionist China, India, Russia and Brazil, and in an era of greater student mobility from the most populous countries. A global dimension may be encouraged by the competitiveness of multinational companies to “exploit location-specific innovation advantages” (Zedtwitz and Gassmann, 2002). However, as global industries slowly respond to sustainable production and development, so too has the premise for international collaboration. Engineering students themselves are entering degree programmes with aspirations of *making a difference*, and primed with the concerns of, for example, climate change, poverty and human inequalities (Alpay et al., 2008). Many University educators have responded to this need by re-evaluating engineering content and pedagogy. Typical initiatives include: creating core courses on sustainable development (see the discussions of Perdan et al., 2000); project-centred learning around complex, real-life and socially pertinent topics (see e.g. Carlson and Sullivan, 1999; Lipson et al., 2007); the provision of service learning and placement opportunities in which students participate in community-relevant work (see e.g. Coyle et al., 1997; Oakes et al., 2002); and the use of multidisciplinary team projects fostering transferable skills and widening the students’ perspectives on cultural and stakeholder issues. Nurturing the global engineer requires a broader professional skills base and a wider awareness of, e.g., international, social, cultural, environmental, political and economic issues. In the past, student development in such areas has been supported through *soft courses* in humanities, stand-alone courses in management and business or through ad-hoc work and study experiences. Currently, much motivation exists in enhancing student skills and knowledge, in which there is some explicit or structured developmental plan towards *global competency*. However, the complexity of such training often necessitates a range of learning experiences with adequate opportunities for reflection and feedback. Often, engineering teachers themselves are unclear as to the facilitation and evaluation of such global skills education.

At Imperial College London, the Faculty of Engineering has initiated a number of cross-departmental schemes to help support the broader, inter-professional and skills-focussed development of engineering students. In this paper, an overview of some of the cross-departmental schemes is given, and some initial evaluation data on their impact on the student learning experience presented. Central coordination of the schemes, in close correspondence with departmental teaching and learning directors, has helped instigate the developments and promote a culture of shared responsibility for engineering education which goes beyond the usual departmental boundaries. An overview of the coordination process is also presented, and will be of relevance to institutions who are attempting to organise educational initiatives across multiple engineering departments.

2. THE CO-ORDINATION OF ENGINEERING EDUCATION DEVELOPMENT

The Faculty of Engineering at Imperial College has committed significant resource to support and develop strategy for Teaching and Learning across all nine engineering departments. Specifically, in 2007 a dedicated group, referred to as EnVision, was formed to support engineering teaching in several ways, including:

- support for departments in course strategy and development
- the attraction of external funds in engineering education
- support for flag-ship projects
- the design and organisation of *teaching celebrations* for recognising and rewarding outstanding teaching contributions or support
- the collection, dissemination and implementation of good practice in engineering education

The core EnVision group consists of 4 engineering academics, 2 learning technologists, a timetabling officer and 2 administrative staff. The group works closely with the Faculty Teaching Committee (FTC), which constitutes the Directors of Undergraduate Studies from each engineering department, and is chaired by the Deputy Principal (Teaching) for the Faculty of Engineering. The EnVision group thus provides consultancy on educational matters to the FTC, as well as administrative, technical and project support for subsequent teaching and learning developments endorsed by the FTC. Unlike many educational support units, EnVision is engineering-specific, led by engineering academics who teach in departments, directly involved in curriculum development, offers core courses to students and does not run staff training on educational development (Imperial's Educational Development Unit provides such training for staff in all faculties). EnVision is embedded in the normal structure of educational strategy and delivery within the specialist Faculty of Engineering.

In the context of global competency for engineers, much opportunity exists for inter-professional skills development through inter-disciplinary, extra-curricular or real-world activities. An advantage of the coordination effort described above was for the set-up of common guidelines, procedures and formats for such activities so as to maximise the student learning experience. Likewise, the coordination helped facilitate new teaching initiatives in which mixed cohorts of engineering students can experience the challenges and rewards of inter-disciplinary work. Central to many of the initiatives is dedicated learning technology support to help in. e.g., activity administration, materials organisation and web-resource development.

In addition to the EnVision/FTC inspired projects, two further schemes are used for the generation and development of cross-departmental initiatives: the Faculty of Engineering Enabled Projects scheme and the Student-Led Projects scheme. The former gives support and funding to innovative projects that have the potential to benefit students and staff in terms of motivation, learning and teaching satisfaction and engineering know-how and skills development. Academic staff are invited to submit proposals on an annual basis, but open-call submissions are also possible to accommodate timely teaching development opportunities. A key condition for proposal support is for multi-departmental involvement or significance. Since 2007, 13 projects have been funded, several of which have direct relevance to global engineering competencies; see section 3 below.

The Student-Led Projects provides students with academic, administrative and financial support in the development of extra-curricular projects of interest to them and, where relevant, advice on continued project funding and management. The range of support is broad and varied, including advice on insurance and legal matters, project dissemination and national and international cooperation. The motto for the scheme is "by the students, for the students", and encapsulates EnVision's desire to encourage students to undertake activities which broaden their professional and transferable skills base, raises their awareness of global citizenship and further inspires them towards their role in society as future engineers. The scheme has a dedicated academic tutor for student support and liaison.

In the following section, examples of schemes being supported by EnVision are presented. These are organised under the abovementioned themes of 'EnVision/FTC inspired', 'Faculty of Engineering Enabled' and 'Student-Led projects'.

3. CROSS-DEPARTMENTAL INITIATVES

3.1 EnVision/FTC-Inspired Initiatives

Two examples of EnVision/FTC-inspired activities are presented to demonstrate the value of coordinated and strategic teaching planning across the Faculty of Engineering. The first involves a change in teaching culture to enable senior-year students to experience a broader range of technical courses, and to engage in group and project work with peers from other engineering disciplines. The scheme was made possible through the set up of a common timetable for one day of the week. The courses, referred to as Flexible Friday Option Courses, are deemed to be of relevance to broader engineering understanding and are offered to students from across the Faculty of Engineering. Examples of courses include Computational Finance, Environmental Impact Assessment, Optimization, Sustainable Electrical Systems, Nuclear Reactor Physics and Design-Led Innovation and Venture Creation. In some cases, the interdisciplinary nature of the learning group has motivated staff to develop innovative courses to capitalise on the potential for creative and non-discipline bounded project work. Current examples of courses being developed include Design of Rehabilitation Systems and Assistive Devices, in which mechatronics, human factors and computer theory are integrated to develop life-quality enhancing devices for an ageing population, and Natural Engineering, in which novel approaches to engineering design and problem solving are considered through analogy with natural physical and biological processes, structures and materials. To date, more than 200 students from across the Faculty of Engineering have undertaken Flexible Fridays Option Courses, and a high level of student satisfaction reported; see Table 1.

The second activity also involves the common timetabling of teaching sessions, but in this case all first-year engineering students are encouraged to attend. The sessions are referred to as the Engineering Impact Series of Lectures (EI) and are aimed to further inspire first-year students towards the role of engineering on society and human development. The sessions cover a broad range of topical themes, and have included presentations on climate change and sustainable development (Jonathon Porritt – Broadcaster and Environmentalist), technology and health (Lord Ara Darzi – surgeon and former Junior Health Minister) and the profession of engineering (Sir Robert Malpas – former ICI and Eurotunnel Chairman). An underling theme of EI is engineering ethics and culminates in a final debate session on controversial issues of relevance to student engineers, e.g. military-related work. Where possible and appropriate, EI is integrated with other departmental ethics or professional awareness activities. To enable maximum student access, and a resource for future teaching, all sessions are recorded on video and made available to the staff and students through the EnVision website.

Table 1 - Descriptive Statistics for the student experience with Flexible Fridays Options Course (N = 43).

	Mean Score (max=10)	Std. Deviation
Overall, I am satisfied with the Flexible-Friday programme.	7.8	1.4
More 4th year options like this should be offered to students.	8.5	2.0
Attending such a course has given be a broader understanding of issues relevant to the different engineering disciplines.	8.5	2.0
Attending such a course has improved my identity as a member of the Faculty of Engineering as a whole.	6.3	2.5
Attending such a course has improved my motivation towards an engineering-related career.	6.6	2.4

3.2 Faculty of Engineering-Enabled Projects

As mentioned earlier, the Faculty of Engineering-Enabled Projects scheme is a way of encouraging academic staff to further engage in teaching developments, especially when this has potential value to students across the Faculty. Some of the funding has been used for the development of new courses for mixed cohorts of engineering students. One such course, the Design of Rehabilitation Systems and Assistive Devices, has been described above. Another major course is Engineering Ethics. Here, effort was given to the development of core teaching material relevant to all engineering disciplines, but with the additional development or identification of materials for discipline-specific contextualisation. Historically, the teaching of ethics has been regarded as falling within the realm of Humanities, but this creates difficulties in establishing teaching content which engages the interests and motivation of engineering students. However, clear Faculty-level commitment to such a course led to much engineering staff motivation for its context-specific development.

In a similar way to Engineering Ethics, some projects have helped to give greater clarity on Faculty-wide aspirations on animating and enhancing the lecture experience of the students. For examples, one project has involved the set up and evaluation of in-class electronic voting devices (i.e. *clickers*). Another project has involved the set up of mobile and large-scale mechanics demonstration equipment enabling students to translate 2-D descriptions of problems into 3-D understanding in Bioengineering, Aeronautics, Mechanical Engineering and Civil Engineering contexts.

Other initiatives have focussed on the development of interdisciplinary design projects, such as designing paediatric orthopaedic devices and zero-emission vehicles (the *Racing Green project*). Currently, generic student resources are being prepared to further support a positive and informed (skills-based) approach to creative design through a project titled *Creativity Engine*. In one project, the emphasis has been to further raise student awareness of Engineers Without Borders (an international student organisation) and, where possible, identify models for incorporating multi-disciplinary development projects into the engineering curriculum.

As a means of further promoting high quality and uniform teaching across the Faculty, several projects have focussed on either teaching and assessment approaches or the recognition and dissemination of good teaching practice. Examples of projects include the use and evaluation of *undergraduate* teaching assistants, the Faculty-level training and support of graduate teaching assistants (GTAs) and an award scheme for outstanding GTAs.

3.3 Student-Led Projects

Student-led projects have a long history at Imperial and take many forms. Imperial has many more student societies than the average university (at least twice as many as average) and a growing number of student societies concern international development projects. Imperial has an award-winning *volunteer centre* brokering volunteer labour for charitable projects, and recent surveys show that engineering students are over-represented in the ranks of Imperial volunteers (and, further, women are over-represented as volunteers). But in addition to these formal structures, there are small student groups who recognise a need in society which their engineering skills, knowledge and goodwill can help address, and do take action without seeking formal assistance from the College. Recognising that these informal activities of students are important as inspiration/motivation for students and staff, the Faculty of Engineering designated an EnVision lecturer as the “tutor for student-led projects”, giving her a remit of fostering extracurricular activities which may occur in the summer vacation. Some current examples of student-led projects include:

- e.quinox: for the provision of solar energy in villages in Rwanda, where the main form of energy is paraffin for lamps and stoves. This originated with electrical engineering students. The project immediately attracted official support from the Minister for Energy in Rwanda and the UN Development Programme. The students have been invited to expand the project and are currently investigating how to create a Rwandan NGO specific to the work.
- El Salvador project: where civil engineering students work with an El Salvadorean NGO to provide earthquake resistant homes and infrastructure in villages, or remediate flood damage. This project has run since 2003, and participants who have graduated are now setting up a UK Charity to bolster fund-raising, provide mentoring advice to current participants and access to chartered engineers who can sign off designs.
- Women in SET: i.e. a student society within Imperial which aims to shift the culture so that Imperial’s women (staff and students) become more visible and foster the next generation of scientists and engineers. Successes include commissioning 100 portraits of Imperial women staff and students, which was invited to exhibit at the Greater London Assembly; an annual Open Day for schoolgirls which is persistently oversubscribed, wholly run by the students for future students and specific to engineering; a Robogals project where Imperial students get schoolgirls building robots, to challenge the idea that computers/robotics is for boys; plus a variety of events, lectures and photography competitions aimed at celebrating the successes of women in engineering.

These are just some examples of the type of activity. Other groups include Students in Free Enterprise, the Malawi Bridge Project, the Bolivia Altiplano project, Engineers without Borders, the Rail and Transport Societies work on rebuilding the Welsh Highland Railway, plus various educational, entrepreneurial and volunteering activities. The tutor’s function is to give advice, foster good management practices, play devil’s advocate on feasibility, foster knowledge transfer, suggest apprenticeships for future leaders, assist with writing grant applications, liaise with other staff, encourage dissemination and to encourage students to appreciate the level of sophistication they have achieved in their personal development. Building relations with alumni, negotiating on insurance, coaching on risk assessments, and promoting the activities as inspirational and motivational are all part of the tutor's activities. Networking with key players in the College administration and academic staff transpires to be a fundamental function and work is progressing on creating appropriate administrative support in the College for this somewhat amorphous student activity. Evaluation of the activities tends to come from the end-user of the student efforts and the continued funding of activities is a measure of the esteem in which the projects are held. Students are encouraged to run their own evaluation processes, in keeping with the "by the students, for the students" ethos of these activities.

A different approach to student-led projects is where students are recruited by EnVision to help create materials that will be made available to all students online. An example is the EPOD project. The use of podcasts is challenging traditional communication methods in higher education, with the potential for creating engaging and flexible resources for learning and development. Likewise, podcasts are helping to facilitate a stronger student identity and community within learning environments, replacing traditional student newsletter and website approaches. In this work, an innovative podcasting approach is presented in which there is a strong student-centred and student-led premise to foster and advance engineering education related uses. Podcasts are intended to cover a range of relevant engineering topics such as sharing student views on global, institutional and scientific developments, and disseminating information on unique educational opportunities. Details on the design, set-up and implementation of the initiative are presented (e.g. resource requirements; management and organization structures; maintenance of balanced educational outcomes). An evaluation of the experiences of the team-members is also presented, showing favourable outcomes in skills development, community identity and broader educational awareness.

4. FURTHER DISCUSSION

The examples of cross-departmental initiatives given above illustrate a range of methods and approaches to engage students in skills development and knowledge awareness which goes beyond the discipline boundaries. Central Faculty of Engineering coordination, with distinct support structures and mechanisms, has allowed for a unified strategy in engineering education. For example, the value of extra-curricular activities which have a strong *real-world* engineering or skills-development premise, is better recognised, and students and staff given support in the set up and development of such activities. Currently, efforts are also in place to help students better reflect on their learning experience and capture distinct learning outcomes. Programmes which foster creative design and ethical consideration naturally cross discipline boundaries, and are positively enhanced by student experiences of interdisciplinary projects and sessions. Such programmes also help to create a common identify for engineering, and potentially further student motivation for an engineering career given the range of professional roles and interactions that exist.

The Faculty Enabled projects provided an interesting shift in staff attitudes towards internal funding. Past attitudes were very much based on a competitive bid, with a "getting something for our department" approach. However, the condition for multiple department involvement and value, as well the necessity for a careful appraisal of possible shared resources, has helped foster a more collegiate approach to teaching development. Furthermore, several instances have occurred where academic staff have recognised the possibility of enhancing their course through the involvement of other engineering disciplines, and thus much motivation for such development work. This of course, is to the benefit to both the teacher and the students alike.

Given the multifaceted approach of cross-departmental initiatives for global engineering education, a multifaceted approach on the evaluation of the initiative as a whole is also needed. An example of programme evaluation has been presented in Table 1. In due course, student feedback on specific courses and projects will also be collected. However, ultimately, the question is: does the College produce engineering graduates who have the skills and knowledge to better succeed and lead in global work contexts? One measure of this is the implicit student motivation for ongoing professional development in engineering, as well as the professionalism they exhibit in working with peers within their department and Faculty. Some data on motivational changes and career intentions has been reported for Imperial College students in the past (see Alpay et al., 2008), and will act as a datum for the impact that the above activities have had on student motivation. Other approaches will consider self-efficacy measures (self-reported and observational) in situations involving, e.g., ethical, complex or person-centred issues.

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Acknowledgements

The authors thank Hannah White-Overton for collecting the data presented in Table 1.

INTEGRAL APPROACH TO ENHANCE ENGINEERING EDUCATION IN AN OFFSHORE UNIVERSITY CAMPUS

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Abstract: The relevance of engineering education to the needs of rapidly developing industries in the Gulf region of the Middle East is of paramount importance. Heriot-Watt University has taken a lead in setting up a campus in Dubai to offer British education to students from the Gulf region and beyond. Conducted surveys have highlighted that one of the centrepieces of the skills most valued by employers in this part of the world are the engineering reasoning skills of graduates. This paper describes the development of real life integrative applications complementing normal delivery aligned to produce graduates that can meet the need of local industry and provide at the same time the required skills set that enables them to adapt to rapidly changing industrial and job market environments.

Keywords: engineering education, engineering reasoning skills, international education

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1. INTRODUCTION

Heriot-Watt University is the first UK University to set up in Dubai International Academic City, offering British education to students and executives from around the Gulf and further afield. The School of Engineering and Physical Sciences started offering its four-year BEng (Hons) mechanical engineering degree courses in Dubai during the academic year 2006/2007. The school's intention from the beginning was to produce competitive and well-rounded engineers capable of contributing immediately upon their graduation to the local/regional economies. To achieve this aim and to make the degree offered by the school "the degree of choice" the strategy was to diffuse problem solving skills into the delivery. To accomplish this we needed to contextualize concepts of the engineering reasoning skills into the delivery of individual modules whenever possible. Since the emphasis was to deliver high quality and competitive education, staff had to address the following key points:

- Capture the basic engineering principles
- Develop and enhance engineering reasoning skills
- Employ best practices to diffuse critical thinking and critical appraisals.

To develop an understanding of the skills set highly valued by industry it was decided to complement previously conducted surveys (by the author) with an up to date survey that led to the construction of a survey of surveys covering a time period from 1983-2009 (individual surveys were conducted from 1983–1993, 2004-2005 and 2006-2009). The survey of surveys summary is shown in Figure 1. It is interesting to note that companies that have remained successful to this day ensured that their recruits possessed the top four sets of skills in the figure below.

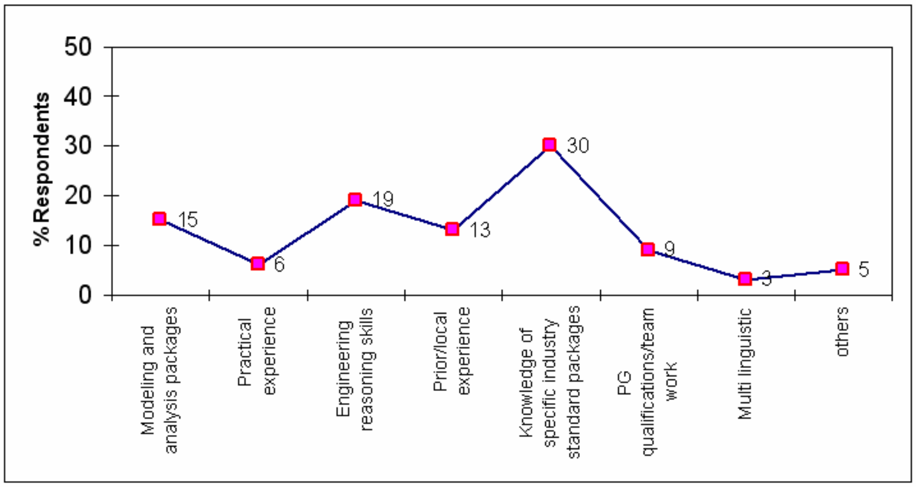

Figure 1: Percentage of companies which stated a particular skill is highly valued

The school capitalized on the remarkable development of Dubai in setting typical life problems/exercises and arranging interactive site visits. All were facilitated due to the close proximity of most landmarks to the campus. This paper presents examples and approaches used in the mechanical engineering course delivery.

2. TEACHING METHODOLOGY

2.1 Engineering Science 2

During semester two, the first year students were required to develop further the core skills of a mechanical engineer. This module provides three components for their engineering toolbox namely dynamics, strengths, and materials analysis tools. Analysis tools must be validated through experimentation in real life situations. Hence the validation of their analysis knowledge is vital to their skills as an engineer. To demonstrate this to the students a project has been developed to test their analysis knowledge gained through attendance at the lectures and modules, which will be validated through experimentation. As we are located in Dubai it was prudent to apply the theme of infrastructure and transportation, both key components of this rapidly expanding emirate.

The project is entitled “Sink or Swim”. The students’ task was to transport a scaled car across a void of water, using only straws, balloons, and tape. The car and tank of water are fixed, the students must use their knowledge and skills to design and build a prototype. This will be tested in the form of a class presentation, thus validating their predictions. The learning outcomes are: a sound understanding of key engineering principles: validation of theoretical predictions; working as a group of engineers; crucially they will experience the consequence of errors in calculations, they will sink or swim-their device will succeed or fail. The overriding purpose is to demonstrate that engineering ingenuity is encouraged but must be backed by sound engineering principles in order to succeed.

2.2 Fluid Mechanics

The approach used in the delivery of the Fluid Mechanics was directed towards promoting the underlying physical concepts rather than focusing on memorizing or merely programming and solving formulae sets. This was complemented by continuously sparking third year students' interest through introducing local and visible problems. As students needed to make logical assumptions and approximations to arrive at reasonable solutions this had led students to appreciate the validity and limits of their assumptions and approximations (in case they broke down). The case below is an example used to present the unsteady isolation of vortices.

When considering a long cylindrical object shedding vortices, the correlation for frequency of shedding is given by:

$$\frac{fd}{v} = 0.198\left(1 - \frac{19.7}{\mathrm{Re}}\right) \quad \text{where:}$$

f=vortex shedding frequency (Hz), d=diameter (m), v=free stream velocity (m/s) and, Re=Reynolds number.

The above formula will generally hold true for a range of Reynolds numbers. Having previously encountered laminar and steady flows which occur at low Reynolds number, students can appreciate the effect of increasing Reynolds number and the onset of flow separation. This occurs at the trailing edge of the cylinder in this type of flow and such behaviour pattern will lead to the formation of stationary vortices in the wake. For Reynolds number between 100 and 200, unsteady oscillating vortices start shedding from the trailing edge of the cylinder, Figure 2. If the frequency of the oscillation reaches the resonance frequency of the cylinder, the amplitude of the oscillation will increase until structural failure. It was decided to arrange a visit to Burj Khalifa, Figure 3, and to form small groups to work on analyzing the forces on the structure based on the theory given above. Students were also given simple portable wind meters to measure local wind speed. Theoretical analysis of flow around cylinders similar to the flow at 100 Re was related to the aerodynamics on complex building design.

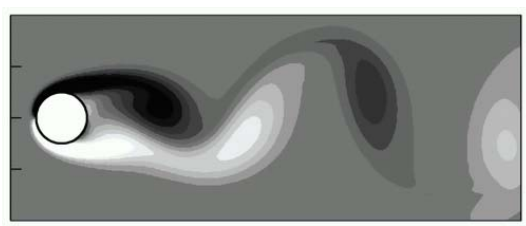

Figure 2: Vortex shedding behind a cylinder when Re=100, Barkley (2006)

All the groups were able to use their acquired knowledge to estimate flow distribution along various cross sections of the burj and arrived at a generally reasonable answer that: considerable reduction in forces due to wind loading could be achieved by encouraging disorganized vortex shedding for the burj structure. An unexpected bonus was creation of interest in Computational Fluid Dynamics, which could be defined as software that combines complex fluid theory with Computer Aided Design through a simple user interface. Thus, the traditionally laborious task of complex iterative mathematical solutions is condensed into a simple methodology. Moreover, the visual output display of the solution engages the students with practical applications of fluid dynamics. The data obtained from the site visit was used as boundary conditions to the flow simulation exercise.

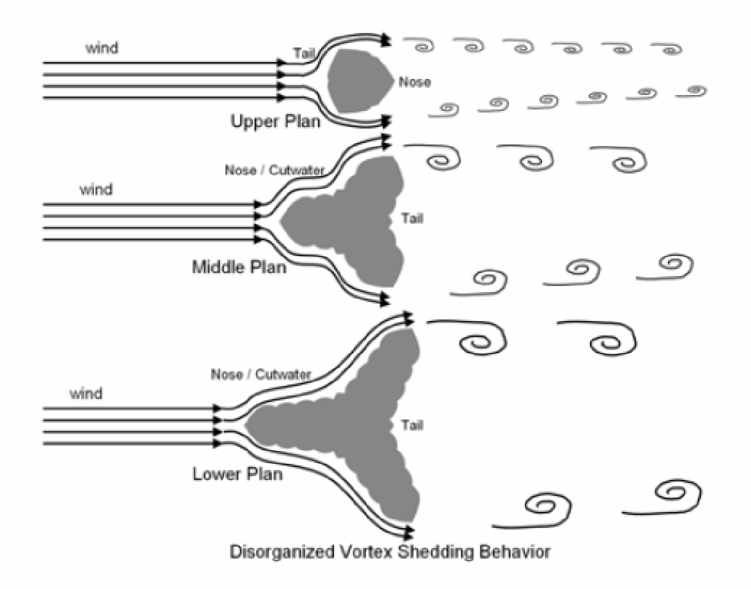

Figure 3: Vortex shedding behavior, Baker et al (2008), and the Burj Khalifa structure

2.3 Thermodynamics

It is widely accepted that the standard of living of different people living on earth depends on their per capita consumption of energy. A fact which is not so well known is that quality of life first rises with rising standard of living and then starts to decrease with further increase in standard of living as a consequence of environmental worsening conditions, e.g. Lagarias (1960) and WED (2007). Since energy consumption per capita is the most important indicator of standard of living, the natural consequence of sharp increase of energy consumption is the deterioration of our climate. Our primary source of energy is fossil fuels or hydrocarbon fuels. Increasing use of these fuels is responsible for obnoxious emissions of greenhouse gases including CO_2 , Figure 4, EIA (2009), below highlights power consumption and CO_2 emissions past and projected. A proper understanding of thermodynamics is necessary in order to improve thermal efficiency and reduce emissions from external as well as internal heat engines including reciprocating, rotary and rotodynamic types.

2.3.1 Thermal Power Plants

In spite of the importance of thermodynamics for energy conservation and protection of the environment many engineering students develop a dislike for thermodynamics. Consequently they do not find the applications of the laws of thermodynamics to real life problems. At the same time they do not find it easy to get a feel of the size, dimensions and overall cost of power systems and find it difficult to predict the operational efficiency as opposed to the theoretical efficiency of real power plants.

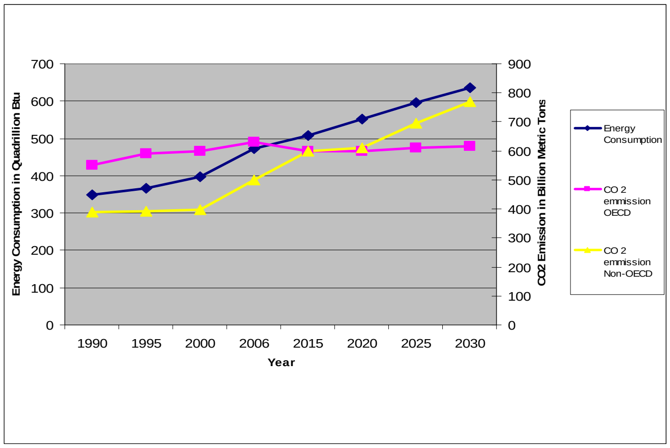

Figure 4: Energy consumption and CO_2 generation over time

A new approach was needed to introduce thermodynamics to our engineering students. It was decided to ask power plant operation and maintenance engineers to interact directly with students and at the same time arrange for site visits for real life data gathering and analysis. The students' first task was to draw a schematic diagram of the power station to get a feel of what is what, how the pieces were arranged and how the entire plant was put together. This was accomplished and a block diagram similar to Figure 5 was produced by students.

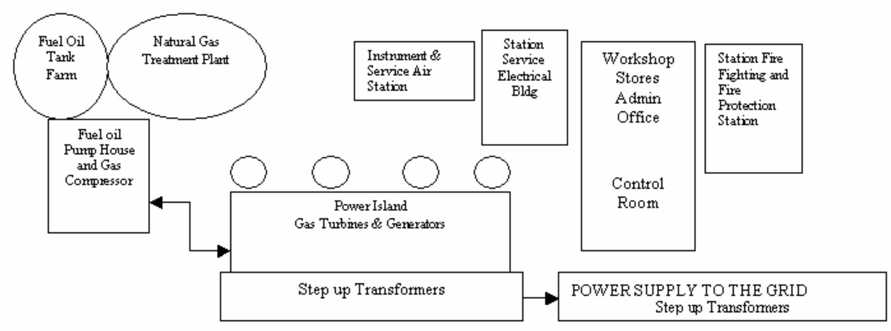

Figure 5: Simple schematic showing an open cycle power plant

Groups of third year students were then asked to carry out performance calculations based on the data that they obtained from plant engineers.

2.3.2 Thermal efficiency calculation

Calculation and subsequent analysis of data enabled students to conclude that the gas turbine thermal efficiency varies with the ambient temperature and that the inlet temperature of the gas turbine is a limiting factor which is limited by the turbine blade metallurgy. Hence they observed turbine thermal efficiency would be de-rating upon rise in ambient temperature and humidity. It was also concluded that achievement of maximum thermal efficiency and maximum specific work in power producing plants (gas turbine) was dependent on:

- Operating conditions such as the ambient temperature and ambient humidity among others.
- Advancing the basic thermodynamic parameters (such as turbo-machinery poly-tropic efficiency, turbine inlet temperature and compressor pressure ratio).
- Use of better materials able to withstand higher turbine inlet temperatures.

- Introducing additional features such as recuperation, inter-cooling, re-heating, water injection, among others.

Students were then able to produce a graphical analysis of the actual power plant at various loads as shown in Figure 6.

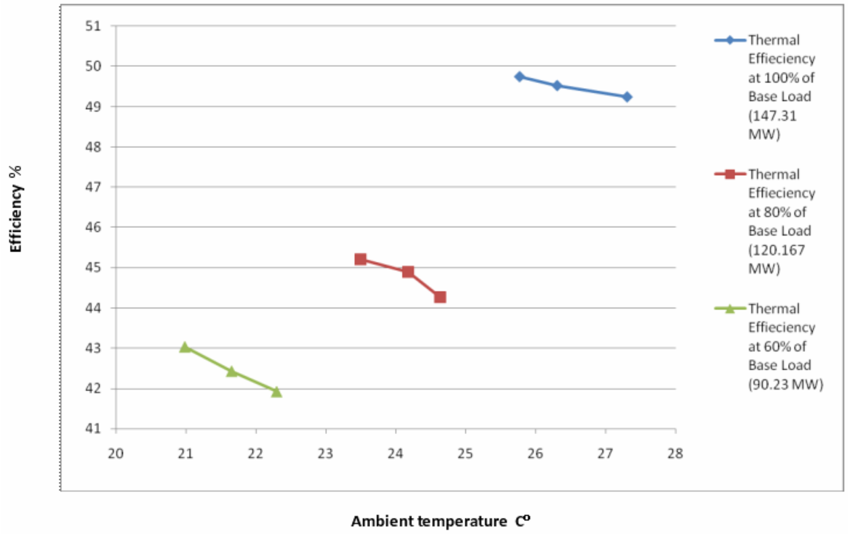

Figure 6: Graphical representation of the behaviour of gas turbine thermal efficiency at various loads and varying ambient temperatures

3. STUDENTS' EDUCATIONAL EXPERIENCE

While it is difficult to pin point the effect and influence of the above-mentioned delivery initiative and delivery strategy on every aspect of students' educational experience, the outcome could be qualitatively assessed by observing a number of indicators including:

- The academic prizes won by our students year on year. Figure 7 shows the percentage increase in outstanding merits awards and awards for taking the highest place in the year across the school and across the campuses. In the 2008/09 academic year there were three times more prizes won than in the first year of operation (this is high even after factoring the effect of increased students' numbers). No change to the course or entry qualifications was made during the period in question.

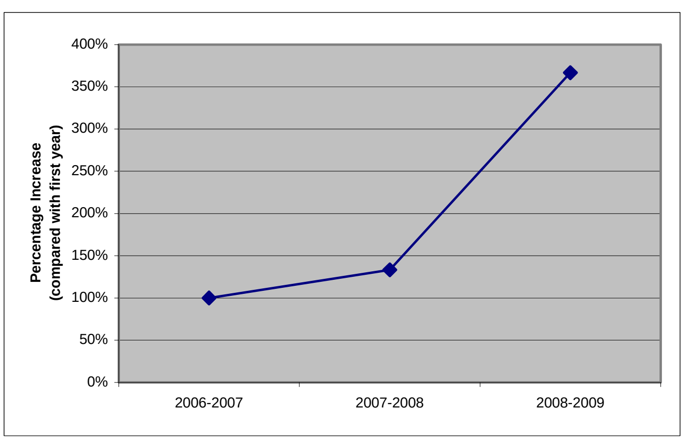

Figure 7: Academic awards by academic year

- Pass rate. Figure 8 compares the pass rates between the university's campuses in the Mechanical Engineering modules delivered during the academic year 2008/09. It is noteworthy to mention here that all Dubai exam scripts were moderated and passed through the same modules and progression board. The results show a consistently higher pass rate at Dubai in most modules from those surveyed. It could be argued that this was a consequence of using local examples and open-ended problems (e.g. Mourtos 2004) as everything else was identical.

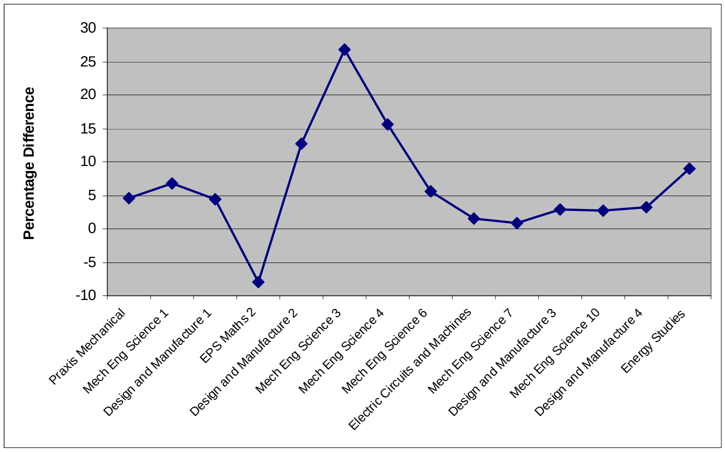

Figure 8: Pass rate compassion Riccarton vs. Dubai for academic year 2008-09

Students' satisfaction and enrolment numbers. Figure 9 shows students satisfaction survey results from recent years and the percentage year on year enrolment in the courses at Dubai. It can be seen that satisfaction rate is on the increase every year and around 86% of students' population are satisfied at 2008/09. Enrolment has also increased year on year. The steady increase in the enrolment is accounted for by three key factors: active participatation by the school's staff in the programme of secondary school visits, widespread positive word of mouth communication from current and graduate students and very successful response rates from the on-campus university open days.

4. CONCLUDING REMARKS

- Demonstrations of the relevance of engineering education are necessary to show the applicability of theoretical concepts to real life engineering problems.
- Examples of the use of some core mechanical engineering subjects to solve practical problems have been given to emphasize the relationship between theory and practice.
- Hands-on exercises and carefully supervised discussion groups were found to be effective tools to arouse interest and stimulate the sense of enquiry. The students' overall performance indicated that the approach used was and is working as quantified by the academic awards received since the 2006/07 academic years.
- High percentage of last year's graduates secured jobs soon after graduation.
- Engineering reasoning skills development through frequent use of open-ended problems at ill-defined situations in which students had to make major assumptions is believed to offer the best way forward to producing capable engineers able to work even outside the immediate discipline area.

The efforts spent are believed to have made our engineering delivery stimulating for students, as our survey has shown. It was also possible to address and improve vital skill sets that are demanded by industry and necessary for today's job market place. These endeavours have enhanced our academic reputation, which translated into improved enrolment.

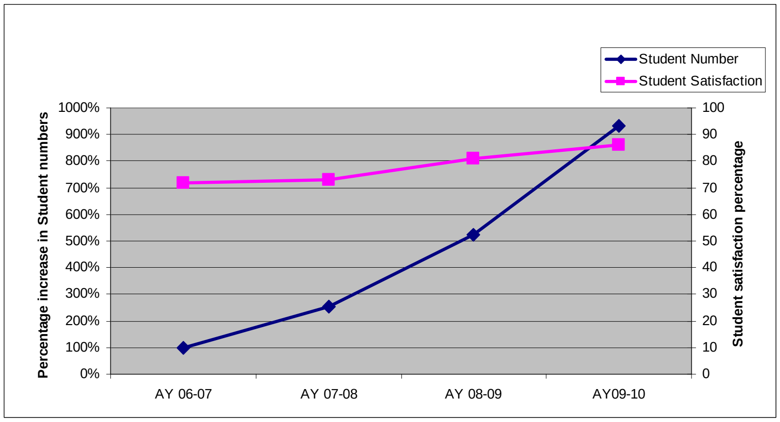

Figure 9: Percentage enrolment year on year and students' satisfaction

5. ACKNOWLEDGMENT

Contribution of academic staff, past and present, of the School of Engineering and Physical Sciences, Heriot-Watt University-Dubai Campus is gratefully acknowledged and so is the support of the Head of Campus.

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THE EFFECT OF UNIVERSITY PARTNERSHIPS ON ENGINEERING EDUCATION IN AFGHANISTAN

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Abstract: This paper discusses the context, the recent development and the present condition of engineering educational institutions in Afghanistan. In addition, the importance of the Afghan government initiative to establish partnerships between selected Afghan universities and the universities in more developed countries will be highlighted in this paper. The discussions and conclusions outline promising directions for this work and consider the lessons learned.

Keywords: Engineering Education, partnerships, Afghanistan.

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1. HISTORY OF EDUCATION IN AFGHANISTAN

Modern education in Afghanistan began with the establishment of its first secondary education school in Kabul in 1903 with the main objective to train the civil servants for the Afghan government. However, the establishment of higher education in the country only started in the 1930's, and continued in the 1950's-1970's (Samady, 2001). It has been well known and widely publicized that the infra structure of Afghanistan was totally destroyed through the decades of wars and instabilities in the country. Amongst other domains, the higher education sector was not only decimated, but had been misused by politicians in order to achieve their short-term political objectives. The majority of well qualified and experienced academics were forced to leave the country, retired or killed. Those academics that stayed behind were isolated from the rest of the world and remained detached from the enhancement of education, knowledge and the development of new technologies. The colleges and universities infrastructure suffered in the wars; for instance, laboratory equipment and libraries have been looted or burned, and most of buildings have been damaged. Furthermore, the curricula have stagnated for decades and neither has there been staff development of suitably qualified and experienced academics or technical staff who are able to educate the students to face the challenges in Afghanistan in the 21st century (Baha, 2003).

Engineering education has a relatively long history in Afghanistan but because of the instabilities in the country, this sector like many others, has experienced catastrophic decline. Several Engineering and Technical Vocational Educational (TVE) institutions were established in the capital and some other major cities between 1930's – 1980's: the most successful ones established with the help and technical assistance from countries such as Germany, the US and the USSR.

The paper discusses the history, present conditions and the progress of Engineering and Technical Vocational Educational (TVE) institutions in Afghanistan. It is recognised that the establishment of Engineering and TVE institutions is vital for the reconstruction and future development in the country. Therefore, recommendations are made as to how TVE and Engineering education in Afghanistan may be re-established to meet international standards and to address local needs.

In addition, the ministry of higher education (MoHE) in Afghanistan has recently established partnerships between the Universities in Afghanistan to selected universities in the developed world. The operation and effectiveness of such partnerships will also be discussed in this paper.

2. THE PROGRESS AND THE PRESENT SITUATION

The Afghan higher education (HE) system has experienced significant improvement (1974 – 1978); however, the destruction of the higher education was begun with the establishment of first pro-communist government in Afghanistan in 1978. Moreover, the HE system was further downgraded after the USSR direct intervention and successive civil wars between the periods of 1980 – 2002.

After the intervention of the international community in 2001 and the subsequent establishment of the new government in 2002, limited progress has been made to rebuild the education sector specifically in engineering and Technical Vocational Education (TVE) (Baha, 2008).

Efforts have been made to improve this sector during the last seven years; some examples of success include:

- An increase in the number of students;
- The establishment of uncoordinated new institutions for political reasons;
- The training of some junior lecturers at universities in the developed world;
- Some limited improvement of the physical infrastructure of selected Afghan universities.

Despite the above efforts, the quality of education provided by the universities in Afghanistan has not considerably improved. However, most institutions are functioning with limited resources and inadequate investment.

3. EVALUATION OF THE SUITABILITY OF THE EXISTING ENGINEERING EDUCATION PROGRAMMES

The University of Brighton (UoB) has established several partnerships with Kabul University (KU), Kabul Polytechnic University (KPU) and Information and Communication Technology Institute (ICTI) over the last four years. The authors have visited these institutions and have evaluated their existing programmes. The following deficiencies have been found:

a. The curricula have not been updated for decades;
b. The curricula are not supported by suitable experimental work;
c. Some of the programmes are less relevant to local need;
d. Most of the programmes are only theoretical;
e. ICT has not been integrated into many courses;
f. There is strong evidence of the lack of application of up-to-date teaching and learning paradigms.

The proposed partnerships between the Afghan universities and universities in more developed countries have provided a unique opportunity to address some of the above issues. However, the success has been limited because of the following reasons:

- There is strong resistance for change by some senior academics at the Afghan universities
- Regrettably, there is a lack of strong leadership at the MoHE and Afghan Universities
- The bureaucratic, long processes at the MoHE and perhaps at the World Bank have hindered the equipping the laboratories at Universities.

The resistance from senior staff is not particularly surprising, as they have been starved of resources for many years but now see external influence threatening their existing values and way of life, even though it brings material improvements. A major challenge is to find ways that they can engage with these changes and feel ownership of the outcome.

4. THE PARTNERSHIPT BETWEEN THE AFGHAN UNIVERSITIES WITH THE UNIVERSITIES IN MORE DEVEOLPED COUNTRIES

Some progress has been made to address the issues discussed in the previous section; however, further serious work is needed to improve the higher education sector. One of the reasons behind any success has been the establishment of partnerships between the Afghan universities and universities in the developed world.

The five major engineering institutions in Afghanistan have established a kind of partnership with well-known universities in the US, Europe, and Asia through a World Bank sponsored program entitled the Strengthening Higher Education Project (SHEP). The aim of this program is to promote strategic planning and the introduction of a development and reform program at key higher educational institutions. According to the author's knowledge, the list of the Afghan engineering institutions and their international partners include:

a. Faculty of Engineering, Kabul University, Afghanistan, with Kansas State University, and Ohio University, US, and with some institutions in Japan;
b. The departments of Electrical Engineering and Computer Engineering and IT, Kabul Polytechnic University, Afghanistan, with the University of Brighton, UK;
c. Faculty of Engineering, Nangarhar University, Afghanistan, with San Diego State University (SDSU), USA;
d. Faculty of Engineering, Herat University, Afghanistan, with the University of Hartford, USA;
e. Faculty of Engineering, Balkh University, Afghanistan, with Asian Institute of Technology (AIT), Thailand.

A major component of these partnerships is the training of selected junior lecturers for the universities in Afghanistan. According to information from the MoHE, around one hundred and fifty individuals have been engaged at various postgraduate programmes at partner universities in the developed world. It is hoped that the return of these young lecturers will have a major effect in enhancing the provision of education at their respective university departments in Afghanistan.

Furthermore, the curricula of certain departments have been updated and the list of equipment and materials has been provided to support the curriculum. It is highly recommended to the MoHE and donor agencies such as the World Bank in this example to supply and equip the laboratories.

The success of the above and other partnerships should be closely monitored by the Afghan government and the World Bank. The Afghan government needs to explore the possibility of close collaboration, including student and staff exchanges with educational establishments through USAID, the British Council, the European Union, Japan, China, India, various UN agencies, and other bilateral cooperation.

Afghan expatriates working at colleges and universities in the Western world can play an important catalytic role in re-establishing proper technical vocational and engineering education in Afghanistan. Afghan expatriates teaching at such institutions in the Western world will have up-to-date knowledge in their disciplines, could easily comprehend the existing situation in the country, could be instrumental in bringing rapid changes, and would know how to properly use the resources. These academics could participate in short-term training of the existing staff at the institutions of higher learning in Afghanistan. Expatriates could help in preparing curricula, training junior academics, and offering timely seminars in the urgently needed areas of each institution. However, it must be recognised that there may be some internal resentments or jealousies that could hinder acceptance from the indigenous academics.

5. CONCULSIONS

The history, recent development and the importance of international partnership on engineering education in Afghanistan has been investigated in this paper. Because of the efforts from the Afghan government, the Afghan Diaspora and international community, limited progress has been achieved.

The major achievements of establishing that partnerships are as follows:

a. The training of selected junior lecturers

b. The updating the curriculum of selected subjects

c. The limited improvement of learning resources

From the authors' point of view, the following challenges remain unresolved:

1. The management at the Ministry of Higher Education (MoHE) and universities is not strong and they lack direction and vision for the future. Furthermore, they are unwilling to change their practices or attitude: a major issue that has to be addressed. It is regrettable that some appointments of such officials at senior positions may not be made on merit but are based on their political affiliations and other reasons.

2. There is little evidence amongst some of the colleagues for respecting the rule of law within the MOHE and universities in Kabul. For instance, clear cases of discrimination have been witnessed at the appointments of junior lecturers and their subsequent selection for the scholarships or other training programmes at universities in the developed world. There is clear evidence to prove this claim, but little consequence to the perpetrators.

3. There are several multi-million USAID and World Bank projects running at the MoHE, nevertheless, the outcomes of these projects have been limited. Better management can prioritize projects and will have a major influence on the effectiveness of such projects.

4. The management at the MOHE and the universities changes regularly and most managers do not continue the programmes of their predecessors, which leads to an unstable system there. Institutions need longer-term vision and plans.

5. Because of the above and other weakness, the real issues to update the curriculum, equipping the laboratories in subjects related to science and technologies, updating the skills of the academics have been difficult to adequately address.

6. The quality of graduates has been very poor and the majority lack technical knowledge and necessary practical skills, which is highly desirable in Afghanistan.

7. The general social instability and pervasive culture means that there is little incentive for personal or staff development within these institutions. This pushes innovators in education to work abroad.

It is a huge task for the people of Afghanistan to overcome the catastrophic destruction of her institutions and educational infrastructure and to address the above issues. This task cannot be accomplished without significant contribution from the international community. In order for the Afghan population to take a role in their country's present reconstruction projects, the Afghan government needs to be proactive in attracting international assistance in building its human capacity. This fact has been recognised, and recently reported by the UN (Eide, 2010). Thus, the following recommendations are made to further improve the higher education sector including engineering education in Afghanistan.

5.2. Recommendations

Improving science, technology and engineering education is essential for countries such as Afghanistan, as a well-educated technical workforce can accelerate development in the country. The following recommendations are made to enhance higher education including engineering education in Afghanistan:

a. Strong management teams are needed at the MoHE and universities in order to tackle the above problems and lay down the foundations of suitable higher education system, which will address the real issues in Afghanistan. These teams need to have suitable experience and a clear vision of how to further develop the education system.
b. Despite the fact that the curriculum of selected subjects has been updated, there is a strong need to evaluate and to improve the quality of all the existing degree programmes, i.e. update the curriculum, develop appropriate educational paradigms, refurbish and re-equip the laboratories in science, engineering and technology-based subjects.
c. The establishment of a council for promoting the education of science, engineering and technology is essential for the country, as engineers and scientists have a collective responsibility to improve the lives of people around the world including Afghanistan. Many expatriate Afghanis may be happy and willing to help here.
d. There is a strong need for better planning to create a higher education system that can address the present problems of the country and it is sustainable in the long-term using the local resources rather than being dependent on international aid.
e. There is certainly the lack of professionals at the MoHE and Universities to prioritize and to control the multi-million Dollars USAID and other funding agencies funded projects in this sector, as the success of such projects in the present time are rather limited and less evident.
f. The expansion of practical vocational and technical courses is highly recommended to be integrated within the higher education system. The practical skills that the University graduates in Afghanistan can offer is very limited at present, which leads to ineffective practitioners trying to maintain the country's technical infrastructure.

g. If higher education, including engineering education, is to play a vital role in the reconstruction and future development in Afghanistan, significant investment in control and resources is needed to address the issues discussed in this paper.

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MANUFACTURING ENGINEERING EDUCTION ACROSS EUROPE

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Abstract: A comprehensive study was conducted investigating the manufacturing engineering education across several European countries, with the main objective to gather information about the syllabi of both mechanical as well as industrial engineering courses at the undergraduate level (first degree courses) offered by the institutes concerned, and to determine the manufacturing-related content of these courses.
The research revealed that on a Subject Group basis both the maximum (taking into account all optional modules the students can take) and the minimum amount of manufacturing education provision (only considering the compulsory modules) for a particular course varies quite considerably between the institutes concerned. This might pose as a stumbling block to students' mobility/interchangeability. The research also revealed a correlation between the extents of teaching and the research interests.
In addition, it was observed that design- and management-related subject areas are considered 'key' subject areas by many of the institutions involved.

Keywords: Manufacturing education; First degree courses; European Universities.

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1. INTRODUCTION AND SCOPE OF THIS STUDY

The FP6 Innovative Production Machines and Systems (I*PROMS) Network of Excellence was established to address manufacturing research in order to reshape this research area and overcome its current fragmentation. One of its many objectives was to analyse the manufacturing engineering education provided by European Universities, which was done in two phases. During the first phase [I*PROMS, 2008] manufacturing-relevant modules, offered by various institute, all of which were partners within I*PROMS, were identified. Although this allowed ascertaining the total amount of manufacturing modules and topics offered, it was thought that it would be useful to explore in greater detail which individual knowledge/skills was provided.

This second phase study [I*PROMS 2009] attempted to be specific by taking into consideration the manufacturing education provided by considering the contribution to the knowledge/skills required. A particular module may, and often does, contribute to a number of different knowledge/skills. In view of this each academic institute was asked to assess the percentage of effort/time spent on gaining a particular knowledge/skill for those modules which in the first phase had been identified to be relevant to manufacturing. The participating institutes were the Universities of Manchester, Cardiff, Newcastle, Warwick (all UK), Clausthal and Hannover

(Germany), Naples (Italy), Patras (Greece), Sakarya (Turkey), ENIT (France) and Dublin City University (Ireland). Only first degree (undergraduate) programmes in both general/mechanical engineering and industrial/manufacturing engineering were considered.

2. ANALYSIS OF KNOWLEDGE/SKILLS PROVISION

The raw data provided by the individual institutes was 'weighted' by considering the number of credits for each module, and expressed as a percentage of the total degree programme. Both the maximum (taking into account all optional modules the students can take for a particular course) and minimum amounts of manufacturing education provision (only considering the compulsory modules) were considered. Because of the large number of different subjects, considering individual knowledge/skills would have made the analysis somewhat difficult. In view of this the discussion of the data was, in general, undertaken with respect to the following Subject Groups:

(i) Conventional Manufacturing Processes: conventional machining, forming, casting and moulding, joining and assembly.
(ii) Advanced Manufacturing Processes: non-traditional machining, rapid prototyping and reverse engineering and CAD/CAM/CNC technology.
(iii) Precision Engineering: micro/nano technology, quality assurance and inspection.
(iv) Design: drawing interpretation, design/design for manufacture, finite element modelling, rapid prototyping, life cycle engineering, joining processes and assembly.
(v) Process Automation: robotics, automation, instrumentation and sensors.
(vi) Management: lean manufacturing, production organisation and control, materials resource management, cost control, global manufacturing and project management.
(vii) Other: knowledge/skills not directly relevant to I*PROMS core-competencies.

Calculating the maximum amount of educational provision is rather complex, as one cannot only consider the maximum number of optional manufacturing modules a student could take, but has to deal with specific knowledge/skills and not manufacturing as a whole. The degree programmes at Cardiff, Clausthal, Hannover, Manchester, Naples and Sakarya are either compulsory or students can take all the options. However, for some degree programmes a student may only take a limited number of the manufacturing options available. While one could analyse all the different programmes it would be somewhat unwieldy. In view of this a compromise situation was used by assuming that all the optional modules can be taken, but with a reduced credit rating. This led to (i) some knowledge/skills training being included which a particular student may not receive, and (ii) a reduction in the time spent on the knowledge/skills training included, with the actual reduction depending on the number of optional modules.

2.1 General/Mechanical Engineering Degrees

With respect to Subject Groups the maximum and minimum amount of provision is shown in Table 1. It is readily seen that the amount of manufacturing education provision varies significantly between the different degree programmes. The variation in some cases being very large, e.g. Cardiff spends more than eight times the time on process automation than Naples. It should be noted, however, that Naples also offer an Industrial Engineering degree where the time spent on process automation is much higher. With the exception of Patras all the degree programmes spend a significant amount of time on design. Patras, however, has a high percentage of project work and some of this may well include design. The degree programmes at Warwick include a significant amount of management, although not all of it is relevant to I*PROMS, as the high percentage of time spent on 'other' knowledge/skills reflects.

		Cardiff	Clausthal	Dublin	Manchester	Naples	Newcastle	Patras	Sakarya	Warwick
Conv. Manuf. Processes	Max	1.3	3.6	5	4.7	4	4	3.7	6.7	1.7
	Min	1	2.7	5	3.1	4	0.7	2.6	1.4	1.7
Adv. Manuf. Processes	Max	2.7	1.7	2.6	5.4	4.5	4	2.5	3.1	1.3
	Min	1.9	1.4	2.6	1	4.5	0.5	0.9	1	1.3
Precision Engineering	Max	4	2.2	1.3	4.5	1	4.3	1.2	1.4	4.8
	Min	0.8	1.1	1.3	0.1	1	0.6	0.5	0.1	0.9
Design	Max	9	10.4	8.6	11.8	8.2	8.4	2.4	7.1	13.2
	Min	4.6	7	7.2	9.4	8.2	4.4	1	3.3	8.5
Process Automation	Max	8.8	1.6	4.3	1.9	1	6.9	3	2.7	4.5
	Min	3.3	1.6	2.9	0	1	0	1.2	0	0
Management	Max	8.3	2	9.7	6	6	4.6	3.2	2.6	7.5
	Min	6.9	2	8.5	6	6	0.8	1.2	0.3	3.4
Other	Max	5.6	1.2	3.8	3	7	1.3	4.8	0.9	18.6
	Min	4.4	1.2	3.6	3	7	1.3	0.1	0.3	12.3
Projects etc.	Max	8.3	18.5	2.1	12.5	10	10.4	28.8	0	6.3
	Min	4.2	0	2.1	6.3	0	10.4	0	0	6.3
Non Manufacturing	Max	52	58.8	62.6	50.2	58.3	56.1	50.4	75.5	42.1
	Min	73.9	83	66.8	71.1	68.3	81.1	92.5	93.6	65.6

Table 1 Knowledge/skills provision as percentage of overall course content - General/Mechanical Engineering

While the minimum design provision is generally lower than the maximum, the reduction, in most cases, is not particularly significant, implying that design is seen as a key subject. To a certain extent the same can be said of management, although in this case the reduction is somewhat greater. Considering conventional and advanced manufacturing processes together, the lowest level of provision is at Cardiff, Newcastle, Sakarya and Warwick. However, Newcastle, Sakarya and Warwick also offer Industrial/Manufacturing Engineering degrees which have significantly more training in manufacturing processes (Table 2).

2.2 Industrial/Manufacturing Engineering Degrees

As in the case of General/Mechanical Engineering degrees, the amount of manufacturing education provision varies significantly between the different Industrial/Manufacturing Engineering degree programmes, see Table 2. To a certain extent this is expected since the degree programmes considered vary somewhat in nature. The programmes at Naples and Sakarya being essentially industrial engineering rather than the more mechanical engineering orientated manufacturing programmes at the other institutes. The highest percentage of 'other' knowledge/skills is again at Warwick. The percentage of time spent on conventional and advanced manufacturing processes at Naples is, at first sight, surprisingly low. It should be noted, however, that the degree at Naples is only of three years duration, thus allowing less time for coverage of certain topics than at other institutes where a significant amount of time is spent on manufacturing in the fourth and, where appropriate, fifth year. It should also be noted that the Naples degree is in industrial/production engineering and it is pertinent to note that they spend more time on manufacturing processes in their mechanical engineering degree.

		Dublin	Hannover	Naples	Newcastle	Sakarya	Warwick
Conv. Manuf. Processes	Max	5	5	3	4.7	6.1	6.1
	Min	5	5	3	4.7	6.1	6.1
Adv. Manuf. Processes	Max	2.6	1.6	1.2	4.6	2	3.6
	Min	2.6	1.6	1.2	4.6	2	3.6
Precision Engineering	Max	1.3	3.3	1.8	3.4	4	6.3
	Min	1.3	3.3	1.8	1.3	4	4.3
Design	Max	8.9	7.6	4.2	8.8	9	11
	Min	7.2	7.6	4.2	7.8	9	10.8
Process Automation	Max	4.3	4.1	3.5	5.9	2.6	4.5
	Min	2.9	4.1	3.5	0	2.6	2.4
Management	Max	9.6	7.5	12.3	4.6	19.5	10.9
	Min	8.5	7.5	12.3	4.6	19.5	7.2
Other	Max	3.8	4.2	12.3	1.3	5.1	19.9
	Min	3.8	4.2	12.3	1.3	5.1	15.5
Projects etc.	Max	2.1	22.1	8.3	16.7	6.7	12.5
	Min	2.1	22.1	0	16.7	0	12.5
Non Manufacturing	Max	62.4	44.6	53.4	50	45	25.2
	Min	66.6	44.6	61.7	59	51.7	37.6

Table 2 Knowledge/skills provision as percentage of overall course content - Industrial/Manufacturing Engineering

In general the amount of time spent on design and management is comparable to that on the General/Mechanical Engineering degrees considered. With respect to management the amount at Sakarya is particularly high but, once again, it should be mentioned that the Sakarya degree is in industrial engineering. On the other hand, the amount of management at Newcastle is somewhat low for a manufacturing degree. However, the Newcastle manufacturing degree is closely linked to their mechanical engineering degree, which also spent less time on management than many of the degree programmes under consideration. Compared to the General/Mechanical Engineering degrees there is little difference between the maximum and minimum provision, since most of the programmes are either compulsory or have few options.

3. CORRELATION BETWEEN RESEARCH INTEREST AND DEGREE PROGRAMME CONTENT

As the previous section revealed, there were significant variations in the type of provision offered. In view of this it was decided to investigate any link between manufacturing education provision and research interests in more detail. This was done via a spreadsheet asking whether, for a particular knowledge/skill, the institute concerned undertook a high level, medium level, low level or no research at all. The level of research at each institute was quantified using a score of “5” for a high level of research, “3” for a medium level of research, and “1” for a low level of research. Zero was awarded if no research in that particular area was conducted. Whilst analysing the Level-of-Research data, it was observed that there was considerable variation for the various institutes. While it was to be expected that there will be variations in research activity between the different institutes, it should be noted that the ‘Levels of Research’ were not precisely defined. It is likely, therefore, that some institutes did, for example, consider their research to be of a high level while another institute did consider the same research to be of, for example, medium level.

Since the knowledge/skills provision reported on in Section 2 was undertaken on a percentage basis, i.e. each knowledge/skill provision was expressed as a percentage of the total degree programme, it would appear reasonable to also consider the level of research on a percentage basis. Thus, the Level-of-Research scores for the various Subject Groups were awarded on a ‘relative’ rather than an ‘absolute’ basis, see Table 3. In this case the percentage is based on the total knowledge/skills maximum for each Subject Group. The figures in bold on grey background indicate a level of research that was above average within each Subject Group.

	Cardiff	Clausthal	Dublin	Hannover	Manchester	Naples	Newcastle	Patras	Sakarya	Warwick
Conv. Manuf. Processes	45	40	**90**	25	25	80	15	15	**60**	35
Adv. Manuf. Processes	**100**	**60**	**87**	**67**	**73**	**100**	40	**60**	47	**87**
Precision Engineering	**100**	10	20	**100**	30	80	**60**	**60**	30	60
Design	40	**87**	57	50	30	**87**	33	**50**	**67**	67
Process Automation	**87**	33	**100**	**100**	7	**100**	**100**	40	**60**	**100**
Management	27	40	**73**	50	**57**	73	0	**60**	**87**	**90**
Average	67	45	71	65	37	87	41	48	59	73

Table 3 Level-of-Research scores expressed as percentage of Subject Group maximum

3.1 General/Mechanical Engineering Degrees

The Subject Groups’ knowledge/skills scores as a percentage of the total degree programme are shown in Table 4, with those Subject Groups having a greater than average Level-of-Research score highlighted in bold on grey background. The table indicates that, in general, those Subject Groups having a greater than average Level-of-Research score have a relatively high knowledge/skill score in relation to the overall average. The main exceptions to this are in Design and Management where it is seen that there are many instances of a high knowledge/skill score even though the Level-of-Research score is below average. It should be noted, however, that these are regarded as ‘key’ Subject Groups and one would expect significant knowledge/skill provision even without significant research activity. In view of this the average knowledge/skill score without Design and Management as well as the overall average is shown. It is seen that using the average without Design and Management shows an even better correlation between the level of research and knowledge/skill provision.

With respect to the Subject Groups of Conventional Manufacturing Processes, Precision Engineering and Process Automation, all the cases – with the exception of Naples (Process Automation), Patras (Precision Engineering) and Sakarya (Process Automation) – have an above average Level-of-Research score coincide with a relatively high knowledge/skill provision. It should be noted though that precise Level-of-Research data were not available for Patras and it may well be that less research is undertaken in Precision Engineering at Patras than was assumed. Table 4 clearly shows that for Advanced Manufacturing Processes, Manchester and Naples are the only institutes showing a clear correlation between the level of research and knowledge/skills provision. Table 3 shows that Naples has significantly higher Level-of-Research scores than most of the other institutes and it may well be that they interpreted the terms high level and medium level more liberally.

		Cardiff	Clausthal	Dublin	Manchester	Naples	Newcastle	Patras	Sakarya	Warwick
Conv. Manuf. Processes	Max	1.3	3.6	**5**	4.7	4	4	3.7	**6.7**	1.7
	Min	1	2.7	**5**	3.1	4	0.7	2.6	**1.4**	1.7
Adv. Manuf. Processes	Max	**2.7**	**1.7**	**2.6**	**5.4**	**4.5**	4	**2.5**	3.1	**1.3**
	Min	**1.9**	**1.4**	**2.6**	**1**	**4.5**	0.5	**0.9**	1	**1.3**
Precision Engineering	Max	**4**	2.2	1.3	4.5	1	4.3	**1.2**	1.4	4.8
	Min	**0.8**	1.1	1.3	0.1	1	0.6	**0.5**	0.1	0.9
Design	Max	9	**10.4**	8.6	11.8	**8.2**	8.4	**2.4**	**7.1**	13.2
	Min	4.6	**7**	7.2	9.4	**8.2**	4.4	**1**	**3.3**	8.5
Process Automation	Max	**8.8**	1.6	**4.3**	1.9	**1**	**6.9**	3	**2.7**	4.5
	Min	**3.3**	1.6	**2.9**	0	**1**	**6**	0.8	**0**	0
Management	Max	8.3	2	**9.7**	**6**	6	4.6	**3.2**	**2.6**	**7.5**
	Min	6.9	2	**8.5**	**6**	6	0.8	**1.2**	**0.3**	**3.4**
Overall Average	Max	5.7	3.6	5.3	5.7	4.1	5.4	2.7	3.9	5.5
	Min	3.1	2.6	4.6	3.3	4.1	2.2	1.2	1	2.6
Average without Design and Management	Max	4.2	2.3	3.3	4.1	2.6	4.8	2.6	3.5	3.1
	Min	1.8	1.7	3	1.1	2.6	2	1.2	0.6	1

Table 4 Knowledge/skills provision - General/Mechanical Engineering

Considering the minimum amount of manufacturing provision, it is seen that with respect to Conventional Manufacturing Processes and Process Automation the situation is similar to that observed for the maximum amount of manufacturing provision. With respect to Precision Engineering the correlation between level of research and knowledge/skills provision is worse while for Advanced Manufacturing Processes it is better. If, as in the case of maximum provision, Design and Management are neglected, then, with the exception of Dublin (Conventional Manufacturing Processes) and Newcastle (Process Automation) there is a significant reduction in the amount of knowledge/skills provision in those Subject Groups having a high Level-of-Research score. This would suggest that these Subject Groups are not seen as 'key' areas to the same extent as Design and Management. It should be noted, however, that in most cases there is still a reasonable amount of knowledge/skills provision in these Subject Groups, indicating that the various institutes concerned do not, in general, let their research interests dominate the compulsory element of their degree programmes. There are, however, cases of significant variations in knowledge/skills provision in non 'key' Subject Groups and, as mentioned above, some of these have above average Level-of-Research scores. The suggestion that research interests influence optional rather than compulsory programme content is supported by a consideration of which knowledge/skills tend to contribute to the differences between the maximum and minimum provision in the 'key' Subject Groups of Design and Management.

3.2 Industrial/Manufacturing Engineering Degrees

The situation for Industrial/Mechanical Engineering degrees is reasonably similar to that for General/Mechanical Engineering degrees. The knowledge/skills scores are shown in Table 5, and those Subject Groups that have a greater than average Level-of-Research score are again highlighted in bold on grey background.

		Dublin	Hannover	Naples	Newcastle	Sakarya	Warwick
Conv. Manuf. Processes	Max	**5**	5	3	4.7	**6.1**	6.1
	Min	**5**	5	3	4.7	**6.1**	6.1
Adv. Manuf. Processes	Max	**2.6**	**1.6**	**1.2**	4.7	2	**3.8**
	Min	**2.6**	**1.6**	**1.2**	4.4	2	**3.8**
Precision Engineering	Max	1.3	3.3	1.8	**3.4**	4	6.3
	Min	1.3	3.3	1.8	**1.3**	4	4.3
Design	Max	8.9	7.6	**4.2**	8.8	**9**	11
	Min	7.2	7.6	**4.2**	7.8	**9**	10.8
Process Automation	Max	**4.3**	**4.1**	**3.5**	**5.9**	**2.6**	**4.5**
	Min	**2.9**	**4.1**	**3.5**	**0**	**2.6**	**2.4**
Management	Max	**9.6**	7.5	12.3	4.6	**19.5**	**10.9**
	Min	**8.5**	7.5	12.3	4.6	**19.5**	**7.2**
Overall Average	Max	5.3	4.9	4.3	5.4	7.2	7.1
	Min	4.6	4.9	4.3	3.8	7.2	5.8
Average without Design and Management	Max	3.3	3.5	2.4	4.4	3.7	5.2
	Min	3	3.5	2.4	2.6	3.7	4.2

Table 5 Knowledge/skills provision - Industrial/Manufacturing Engineering

Considering the Subject Groups of Conventional Manufacturing Processes, Precision Engineering and Process Automation, all the cases, with the exception of Newcastle (Precision Engineering) and Sakarya (Process Automation), having an above average Level-of-Research score coincide with relatively high knowledge/skills provision. With respect to the Advanced Manufacturing Processes there is little or no correlation between research activity and knowledge/skills provision. Advanced Manufacturing Processes provision at Naples is particularly low. However, the Naples programme is very much Industrial Engineering orientated and one would therefore expect less coverage of certain technological subjects. It is pertinent to point out in this connection, that there is a high Advanced Manufacturing Processes provision on the Naples Mechanical Engineering degree.

Since the degree programmes at Hannover, Naples and Sakarya are effectively compulsory with respect to manufacturing provision, there are, obviously, no differences between the maximum and minimum amounts of provision for these institutes. It should be noted, however, that there are many options available at Hannover but data was only available for the relevant compulsory modules and those options offered by only one of University's institutes. The trend at the other three institutes is similar to that observed for the General/Mechanical Engineering degrees, i.e. a tendency towards a reduction in knowledge/skills provision in the non 'key' Subject Groups having above average Level-of-Research scores. This again, with some exceptions, supports the view that the link between research activity and knowledge/skills provision is strongest for the optional modules on offer.

4. CONCLUSIONS

The study highlighted a number of general, non-institute specific, factors which are as follows:

(i) Considerable training in certain knowledge/skills, such as project management, was detected that is not apparent from module titles.

(ii) On a Subject Group basis both the maximum and minimum amount of manufacturing education provision for a particular course varies quite considerably. With regard to student mobility/interchangeability, as proposed by the Bologna declaration [BMWF, 2009], this may be considered as a stumbling block.

(iii) Both design and, to a lesser extent management, are seen as 'key' subject areas by the institutes concerned, as the small reduction from the maximum and minimum amounts of manufacturing education provision indicates.

(iv) Apart from these 'key' Subject Groups, there appears to be a correlation between the amount of knowledge/skills provision and the level of research undertaken. Those Subject Groups having a greater than average Level-of-Research score have a relatively high knowledge/skill score in relation to the overall average for most of the institutions concerned.

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ACKNOWLEDGEMENTS

Funding was provided by the I*PROMS NoE. The authors would like to thank the Universities of Cardiff, Clausthal, ENIT, Hannover, Naples, Newcastle, Patras, Sakarya, Warwick and Dublin City for their contributions. This paper is written in memory of Dr George Barrow, who was the principle researcher of this work. He suddenly passed away in September 2009.

IMPLEMENTATION OF PROJECT BASED LEARNING IN A LARGE ENGINEERING PROGRAMME

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Abstract: The role of the engineer in industry has evolved, with today's engineering businesses seeking engineers with abilities and attributes in two broad areas - technical understanding and enabling skills. Institutions within the engineering community such as Engineers Ireland, the Accreditation Board for Engineering and Technology, the Royal Academy of Engineering and members of the CDIO (Conceive Design, Implement, Operate) initiative have highlighted a need for new approaches to learning and teaching of engineering within our academic institutions. This paper reports on the recent implementation of project based design courses in both of the two engineering programmes offered by Trinity College Dublin. The projects are each carried out in small groups (typically four to six) and are virtually free of podium based teaching. Initially, the students are provided with a design brief, foundation level technical input and raw materials. The projects are developed around the principles of CDIO which represents best international practice for teaching design. The implementation of this methodology requires self-directed learning, teamwork and small group learning, culminating in the actual building and testing of a prototype. Some projects finish with a public competition which tends to generate huge excitement. The new courses have been seen to foster innovation and to provide a format that channels the student's creative skills in a coherent and structured manner. The detail of the courses, the learning outcomes, and the resource overhead are presented as well as a discussion on the initial results from the programmes.
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Keywords; Project Based Engineering, CDIO, Design.

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1. INTRODUCTION

In the last ten years this country has seen dramatic changes to its engineering employment structure. With low "added value" manufacturing in Ireland no longer able to compete with lower wage costs in emerging economies, Irish Engineering must adapt in order to remain viable. The national strategy is to promote a Knowledge Economy. Irish Engineers must be able to "add value" to products, to be innovative and creative, to be customer and business focussed, to think globally and to work in multi-disciplinary teams with mature project management and communication skills.

A common paradigm of engineering third level education sees a first year syllabus which introduces basic engineering sciences and mathematics, proceeding in subsequent years through more applied science and discipline specific technologies, and culminating with a variety of ‘capstone’ courses and a substantial engineering project. In many cases the key engineering skills of synthesis, creativity, design and implementation are only really given full expression at this (late) stage.

1.1 CDIO Context

In early 2000 a group of four universities applied to the Knut and Alice Wallenberg Foundation of Sweden to fund a bold venture that would reshape engineering education in the USA and Europe. This new model, called CDIO (Conceive-Design-Implement-Operate) was to provide future generations of engineers with the knowledge, skills and attitudes required to assume leadership roles in the twenty first century. Since 2000 CDIO membership has spread across all continents with some 30 participating institutions. The stated goals of the CDIO initiative are to develop:

- A deep working knowledge of technical fundamentals.
- A refined ability to discover knowledge, solve problems, think about systems, and master other personal and professional attributes.
- An advanced ability to communicate and work in multidisciplinary teams.
- Skills to conceive, design, implement, and operate systems in an enterprise and societal context.

The CDIO belief is that graduating engineers should appreciate engineering processes, be able to contribute to the development of engineering products, and to do so while working in engineering organizations. The additional implicit expectation is that recent engineering graduates should be developing as whole, mature, and thoughtful individuals. Thus CDIO has the same goals as ABET and Engineers Ireland and so the publications of all three give much guidance on the methods whereby Irish teaching institutions may achieve the improvements to engineering education required by Engineers Ireland for our student base.

1.2 Benchmarking the degree programmes

The School of Engineering at Trinity College Dublin presently offers two four year engineering degree programmes: one leading to the degrees B.A., B.A.I. and the second the B.Sc. degree. Both are fully accredited by Engineers Ireland and by affiliated institutions such as I. Mech. E.

The B.A., B.A.I. degree has two cycles, Freshman (1^{st} & 2^{nd} years) and Sophister (3^{rd} & 4^{th} years). During the Freshman cycle, students study a common set of subjects. After successful completion of the Freshman cycle each student chooses a discipline from one of Civil, Mechanical, Electronic or Computer Engineering, or a combination of the latter two and follows specialist topics associated with their chosen stream over the next two years.

The B.Sc. degree differs from the B.A.I. degree in that the class size is smaller, there is a greater coverage of business and management topics, and the course is focussed on manufacturing engineering from entry level onwards. There is a significant overlap with the B.A.I. course in the Freshman cycle, with increasing specialisation in the sophister years. The small class size and the close control (the course is managed within one department rather than having to co-ordinate across the entire school), give the programme a high degree of agility with regard to implementing curriculum change.

The School of Engineering, TCD, has responded to requirements from new drivers such as: the Bologna process; a new set of industrial requirements and the change to a five year degree programme (B.A.I.-M.A.I.) by restructuring its freshman cycle to a more project oriented programme and by continuing to emphasise design in the B.Sc. degree. Previous works by Bennett 2008; Bennett et al. 2008; Kelly et al. 2008 and Lyons 2005 have discussed issues related to the implementation of CDIO compliant courses into engineering programmes. In each case, the dependence of success on a well designed group activity has been emphasised. Some detail of these and other initiatives is given in this paper.

2. INITIATIVES

2.1 Engineering Design I-Drawing and AutoCAD. B.A.I., 190 students, 1st Semester, Junior Freshman, 5ECTS.

This course contains fundamentals of design, ensuring that the students are equipped with the practical engineering drawing skills that will enable them to undertake design in engineering. On completion of the course, the students can understand and interpret technical drawings conforming design, and are capable of transforming spatial components and structures into drawings thus being able to disseminate accurate designs into a wide range of multidisciplinary professional audiences.

The course consists of two distinctive modules: drawing/graphics and Autocad. In the drawing/graphics module the students understand dimensioned projections and learn how to create two-dimensional images of objects using first and third angle orthographic projection as well as isometric, perspective and auxiliary projection. The students also interpret the meaning and intent of toleranced dimensions and geometric tolerance symbolism. In the Autocad module the students learn to inform and communicate elements of engineering by creating and delivering advanced graphics efficiently with the standard software Autocad.

2.1.2 Teaching Strategies

Lecture periods are interspersed with short tests wherein the student can evaluate their own understanding of the topic at that time. The students, in relatively small subsets of the overall class, undertake a number of formal drawing office sessions and computer laboratory practicals under the guidance of the lecturer and demonstrators. During this time further exercises are undertaken and guidance is available from both lecturers and demonstrators. Notes and quizzes are available to the student on the College website. In addition, a web tutorial guide is available to the students for self directed learning.

2.2 Engineering Design II-Project: Design, Build and Analyse a Roman Mangonel. B.A.I.: 190 and B.Sc.: 20 students. 2nd Semester, Junior Freshman, 10 ECTS.

In order to remain faithful to the CDIO philosophy, it is necessary that the students actually constructed something tangible which can be tested. The Mangonel (Roman catapult), as the core object of the programme, proves itself to be extremely well suited to being at the same time a mechanical device which can be designed, manufactured, analysed and operated and also the subject to which Civil and Electronic Engineering design assignments could be associated.

2.2.1 Syllabus

Groups of students will work together on assignments in the areas of Mechanical, Electronic and Civil Engineering. The assignments will facilitate the Design, Construction and Analysis of a Mangonel. In addition to some introductory lectures, the content of the students’ work during the year will consist of;

- the construction of a Mangonel: provided with Bill of Material (BOM), assembly instructions, parts and tools.
- the development of a software tool to allow the trajectory of a "missile" to be studied as a function of various operating parameters: launch velocity and angle, drag dependent terms.
- a structural analysis of certain key components of the Mangonel for static and dynamic stresses using values of material properties which are experimentally determined;
- the development of a micro-electronic system to allow the angular velocity of the throwing arm to be determined: infra red optical sensors, electronic components, e.g. PicAxe IC, JK Flip-Flops, NAND gates, software developed and uploaded to PICAXE see figure 1 for illustration.
- testing the Mangonel: functionality, distance, accuracy, spring balance to measure torque etc.
- student redesign of the throwing arm of the Mangonel to optimise for distance without compromising structural integrity;
- an inter-group competition at the end of the year: sponsorship from Honeycomb/Radionics etc. Irish Times Coverage (2008)

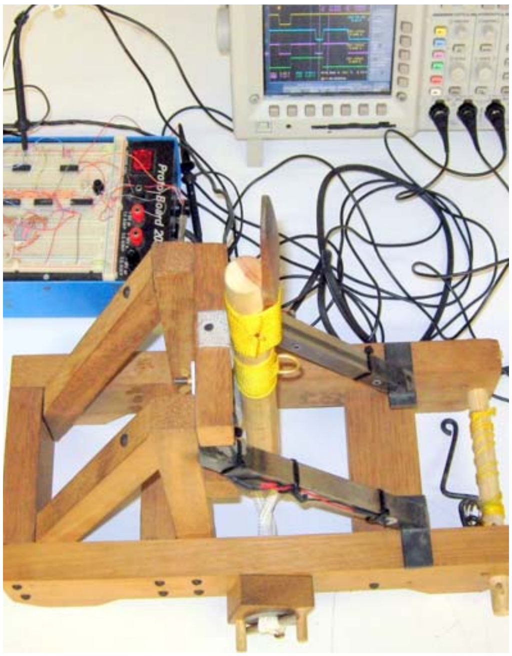

Figure 1. Mangonel with Electronic Circuitry

2.2.2 Teaching strategy and assessment modes

The course is delivered using a combination of introductory lectures and participation by the students in 15 "activities". The activities are executed to support the syllabus of the course and might take place in specialized laboratories or on the rugby pitch. The course is structured using WebCT, where course material may be found and using which assignments are to be submitted. Students work in groups throughout the semester to encourage teamwork, cooperation and to avail of the different skills of its members. The students submit five individual assignments, two group based assignments, and two individual online multiple choice assessments.

2.3 Engineering Design III-Project: Design and Construction of a Refugee Shelter. B.A.I., 180 students, 1st Semester, Senior Freshman, 10 ECTS.

2.3.1 Syllabus

The class is divided into groups of approximately 9-10 students per group, to work on a project comprising an open ended design and build exercise that integrates civil and mechanical engineering. The first part of the project is to design a refugee shelter for an extreme climate with the following design requirements (see, for example, Figure 2):

- The shelter must be light-weight, portable and easy to erect and dismantle.
- The shelter must be designed for a 5 person capacity of their chosen demographic.
- The shelter must be able to store food above ground
- The shelter must have the ability to collect 70L of clean rain water per week, 20L of which must be stored in case of emergency
- The shelter must incorporate a solar cooker for meal preparation
- The shelter must adhere to all these requirements with a maximum cost of €100

The second part of the project incorporates the design of a solar cooker to boil one litre of water based on a solar flux of approximately 1kW/m^2. As the solar cooker is to be designed for developing countries, it had the further stipulation that it could not cost less than €10 and must be made from off-the-shelf components.

2.3.2 Teaching strategy and assessment modes

The course is delivered through a number of lectures and workshops throughout the semester. The students are provided with a wide range of multi-disciplinary lectures including the following: Project Management; Human Geography and Refugee Shelters; People Centred Design and Health and Safety; Sustainability and Recycling; Structures and Design; Solar Cooker and Heat Transfer. The lecture order is structured to encourage creativity and design thinking in the early weeks of the project.

There is no formal end-of-year examination for this subject, but all students must achieve an overall mark of at least 40% to pass. The overall mark is calculated using a combination of group and individual assignments. These assignments account for 60% and 40% of the overall mark, respectively. The group assignments include the following: group report on the interpretation of the design requirements; poster presentation; project management plan; construction and testing of the designs. The individual assignments include the following: structural hand calculations for the design of the refugee shelter; health and safety plan; sustainability and recycling plan; design of a solar cooker.

Figure 2 - Construction of 'The Cardboard Cradle', a design which incorporated recycled cardboard tubes from cardboard manufacturers

2.4 Engineering Design IV-Project: Design of Wireless, Autonomous Vehicle. B.A.I., 180 students, 2nd Semester, Senior Freshman, 10 ECTS.

In this design project students work in groups of about six and are required to design and implement a micro-simulation of a light rail system. The project has been developed this year as a sizable expansion of an earlier very successful design project which required the design, construction and test of line following vehicle. The primary deliverable of this expanded design project is for each group to create an autonomous vehicle, referred to as a buggy, that is under wireless supervisory control from a remote station, see Figure 3.

2.4.1 Syllabus

The objective of the project is to introduce the students to the engineering challenge of electronic and computer systems design. The project is an example of ‘hardware and software co-design’ and the scale of the task is such that it requires teamwork as a co-ordinated effort. Each group has access to a buggy, see Figure 4, a wireless communications module for the buggy, a wireless communications module for a PC and collective access to a test track that includes signalling gantries.

The tasks to be performed comprise i) overall management, final integration, testing and evaluation; ii) “buggy” design and engineering; iii) communications and control systems and infrastructure. Within each of these high-level design goals lie many individual tasks. Each group must identify and strategize for each of these tasks. The group leader(s) will manage and co-ordinate the overall project activities.

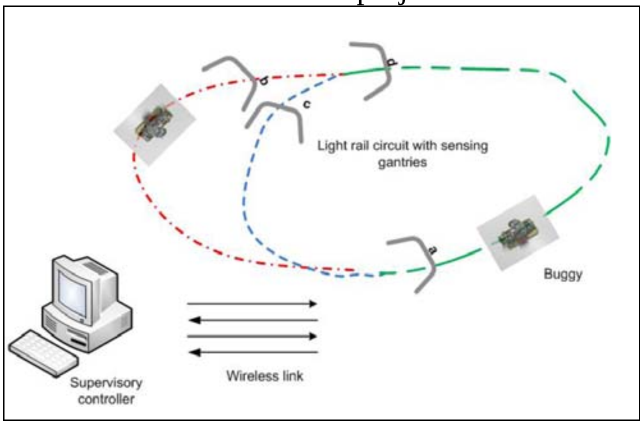

Figure 3. Engineering Design IV - System Overview

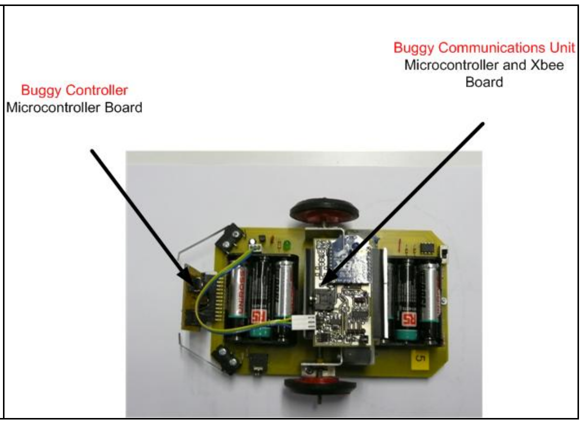

Figure 4. The Buggy and its subsystems

For the project to be a success requires each group to address the following sub-tasks:

Sub-Task1 : Buggy Controller -This task has to deliver the hardware and software (PicAxe) components of the buggy controller. The hardware configuration and behaviour must be agreed with the software developers for incorporation in the controller program. The design and construction of the system introduces electronic circuit testing and requires basic soldering skills.

Sub-Task 2: Communications and Supervisory Control – This task has to deliver the communications where XBee modules are to be used to establish wireless 2-way serial communications between the light-rail controller (PC) and the Buggies. The task also includes the development, implementation and validation of the supervisory control software and agreed communications protocol to run on a PC and on the buggy microcontroller Xbee board.

2.4.2 Teaching strategy and assessment modes

The project work is undertaken by the groups during weekly supervised and unsupervised timetabled sessions. In addition, there is a lecture programme which addresses selected topics relevant to the project and advisory sessions on group working and assessment briefings.

The project is assessed through interim submissions, a demonstration session and a collective final report. The breakdown of the assessment is -1. Interim submissions 30%. 2. Group Buggy demonstration, system inspection and oral assessment 40%, 3. Final Report 30%.

2.5 Engineering with Management Degree, B.Sc.: 20 students, four year programme.

Two areas were chosen to act as testbeds for new CDIO initiatives. These are described below, summarising the pre-existing practice, the new material and the results obtained.

2.5.1 Introduction to Manufacturing

This course had traditionally been podium-based, focussing on the technologies and basic theory, but leaving the relationship with design relatively unexplored. The implicit pedagogical strategy was to provide theory first (this course) and then re-inforce the theory with implementation examples (later design courses). It was decided to amend this strategy – ‘front-loading’ the course with design examples, providing theory as and when required, before returning in the latter part of the course to more traditional theory – with a ‘need’ for this knowledge hopefully having been identified by the student cohort, following their experience in the design based exercises. To this end, the students were randomly assigned to groups on their first day of college and charged with the task of making short presentations to the class. The purpose of this exercise was fourfold – to act as an ‘icebreaker’, to inculcate an ab-initio acceptance and understanding of the importance of groupwork and communication, to encourage students to approach the programme with a suitably enquiring frame of mind, and to prompt the students to consider everday objects from an engineering perspective and to identify technologies important to their manufacture. The subject matter of each groups presentation was to consider the design, manufacture and sale of an everyday object – e.g. a foldable chair, a bicycle wheel, an adjustable spanner etc. Some general feedback was given to the students, and they were asked to work, in groups, on the same task, for a longer presentation in the following weeks lecture. In between they were given information on materials selection methodology. Following the second presentation, the final part of the exercise involved each group taking on the (re-)design of another groups product.

2.5.2. Laboratory Programme

Several limitations were apparent with regard to the existing programme – notably that

- the scheduling requirements meant that the majority of the class were doing experiments a significantly long time either before or after they had learned the corresponding material (e.g. yield strength of materials) in class,
- the large class size (~200 students) meant that there was a significant boredom factor for the graduate students running the lab, as typically it had to be run 50 or so times per year. This was often readily apparent to the students who therefore had little ‘buy-in’ to what appeared to them to be a formulaic exercise.
- There was little or no opportunity for creativity on the part of the students in terms of how the experiment was conducted

Having taken the above limitations into account, it was decided to replace the above programme with one which consisted of 5 separate laboratory sessions, each of which made use of LEGO Mindstorms ™ kits. Mindstorms take the existing LEGO Technical range (which incorporates gears, motors, axles etc in addition to the 'standard' building blocks) and add a programmable control 'brick' and sensors (ultrasound, touch, sound and light). The programmable brick allows for bi-directional communication with a PC via USB or Bluetooth, either 'live' or periodically. The control brick has on-board RAM and is capable of storing programs and data which may be uploaded or downloaded to the PC. The software environment on the PC was developed by National Instruments and has much in common with their LabView™ suite.

The five labs were as follows:

- **Introduction** – the students were given instructions on how the software worked and given some simple tasks to do perform – involving construction and programming of a very basic robot.
- **Calibration Design** – the students were given information on calibration techniques and theory and asked to conceive and design an experiment to calibrate the ultrasound sensor for use as a distance measurement device. They were allowed to use any equipment or materials that they wished to source themselves. Feedback was given during the session on any ideas, from both the demonstrator and academic staff, and students were encouraged to physically implement ideas, where possible, on a trial basis.
- **Calibration Implementation** – the students were required to implement their experiment and to calibrate the sensor. A report template indicating the information required – broken down into boxes, each requiring a paragraph of text - was is given to each student.
- **Measurement Design** – the students were asked to design an experiment to measure the perimeter and surface area of a box. Further information was provided on the theory of experimental error. As with the 2nd laboratory, feedback on suggestions was given and active trials were are encouraged.
- **Measurement Implementation** – the students were required to implement the lab they had designed in the 4th session and to produce a report outlining their results, including inclusive of an error analysis. A list of required headings for the report was is given, but not to the level of structural detail that was provided in the 3rd lab.

3. RESULTS

The success of a newly introduced programme is always difficult to determine as by default there is no benchmark for comparison. In order to gather some structured feedback, anonymous student surveys which take place during the academic year are repeatedly organised. These are performed by the Centre for Academic Practise and Student Learning (CAPSL) and thus are completely independent of the School of Engineering. The survey questions cover all aspects of the course from organisation and evaluation to content. The results tend to be overwhelmingly positive with a typical breakdown of results given in Figure 5. Highly encouragingly, the students are motivated to go to the labs, find the material interesting, and the key goal, are stimulated to think critically about the subject matter. This latter point is one which differentiates the failures of podium based learning from a well structured project based course. In addition to the surveys, student "soundbites" from the students are extremely positive and find the project work, in the context of a week of mathematics and pure Engineering Science, to be more interesting and relevant to their career choice. High student numbers at the labs and a 100% turn out at the competitions are also indicative of enthusiastic participation.

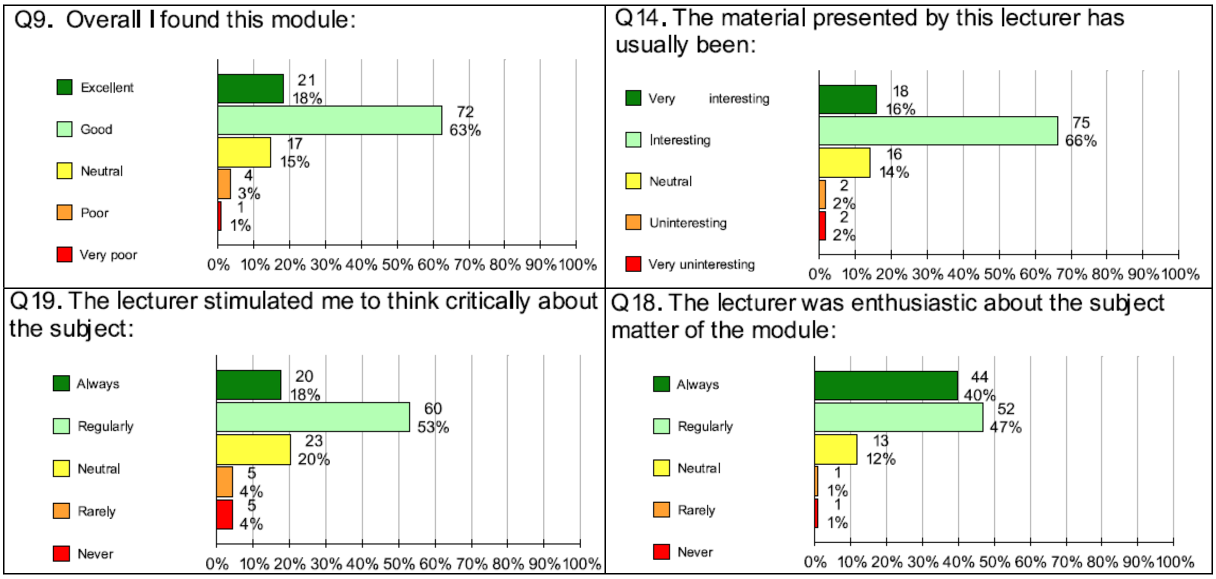

Figure 5. Sample of Results from Student Survey

To assess the new B.Sc. laboratory programme, the students were asked to fill in anonymous questionnaires where comparisons were made with other labs taken by the first year students. These are physics and chemistry for the majority, with several repeat students from the first cohort also having taken the pre-existing engineering labs. An analysis of the results indicates that greater satisfaction is reported for these LEGO labs than for any of the other labs in the programme, with the only positive scores for enjoyment and workload being reported for the LEGO labs. Interestingly, in terms of absolute time commitment, the LEGO labs are on a par with several of the other labs, but there appears to be a negative mental correlation between enjoyment and workload – i.e. students don't perceive the workload as onerous if they are having fun! This inference was reinforced on a practical level by the difficulty in getting the students to conclude experimenting with the LEGO at the conclusion of each session, so that the demonstrator could go home!

4. CONCLUSIONS

The structure of the B.A.I. and B.Sc. engineering degrees in Trinity College Dublin has recently been revised to a more project orientated curriculum. Whilst a strong focus on technical content remains in the syllabi, skills such as communication and teamwork are considered to be an integral part of education and should continue to be fostered. A description, three years after the introduction of the new project based courses, which are inspired by the CDIO methodology, is presented in this paper. The students, provided with only cursory technical fundamentals are encouraged to think critically on their subject matter and as a result address the solutions innovatively in a team work environment. The courses necessitate an initial investment in materials and time but this should decrease to maintenance levels with time. There will continue to be a requirement for a high number of demonstrator staff for the management of this course, however, the positive contribution of the course to the students' development is considered to warrant this expenditure.

5. ACKNOWLEGEMENTS

The authors would like to acknowledge their colleagues who contribute significantly to these courses: Bernadette Clerkin, Seán O'Callaghan, Garret O'Donnell, Mark Dyer, John

Fitzpatrick, Brian Foley, Bidisha Ghosh, Shane Hunt, Garry Lyons, Tony Robinson, Ciaran Simms, David Taylor, Roger West.

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COMPARATIVE STUDIES ON THE TEACHING OF "SUSTAINABILITY" IN THE PROGRAM COURSES OF INDUSTRIAL ENGINEERING FROM FIVE PUBLIC UNIVERSITIES IN BRAZIL.

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Abstract: The importance of exercising the learning related to sustainability emphasizes the justified interest in studying how the institutions in Brazil are building the teaching-learning process for the training of professionals capable of meeting the new challenges of working for sustainable development. To know how universities are organizing to form professional production engineering can promote sustainable development and the practical application of social and environmental responsibility in the labor market, we propose a comparative study of the programs. We selected five public universities in a different region of Brazil and analyzed your programs of courses production engineering. The menus of the subjects were compared between the universities and identified aspects of the practice of the classroom. We note that a preliminary analysis indicates that total hours does not provide hands-on activities in training programs and that higher education institutions surveyed in Brazil encounter difficulties in integrating theory and practice of sustainability to their students and future professionals in production engineering who will work for sustainable development.

Keywords: educacion, sustainability, production engineering, undergraduate course, Brazil.

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1. INTRODUCTION

1.1 Production Engineering in Brazil - Historical Aspects

The engineering industry emerged in the twentieth century in America began in Brazil as production engineering with the creation of the Institute for Rational Organization of Work in 1931, and only since 1959 that subjects specific to production engineering began to integrate the program other courses such as aeronautical engineering from the Technological Institute of Aeronautics (ITA). The graduate emerges in 1966 at the Pontifical Catholic University of Rio de

Janeiro (PUC-RJ) and was created in 1971 the first graduate course in production engineering from Universidade Federal do Rio de Janeiro (UFRJ). Currently there are 317 courses offered in the country at institutions of higher education between public and private (INEP, 2010). These courses in their curriculum organization basically conform to engineering courses in full production, which are those that comprise much of the workload in the study of production management, and courses with specific qualifications that divide the workload between studies of technical systems and management of production, resulting in engineering courses for electricity production, production calendar, mechanical production, among others.

1.2 The Formation of Production Engineering

The Ministry of Education through the National Education Council (CNE) and the Higher Education Council (ESC) provides the CNE / CES 11/2002 in his art. 6, which all engineering course, regardless of their discipline, must have in its curriculum a core of basic content, a core of professional content and a core of specific content that characterizes the discipline. The core is the basic content that establishes the nature of knowledge engineering. This body of knowledge allows the engineer to develop competencies and skills to understand a structure to be created or existing in terms of its various components. The core professional content is what makes the combination of theory and practice of knowledge acquired at the core of basic content. And the core of specific content constitutes extension and deepening of the contents of the core professional content, as well as other content designed to characterize modes. These contents, consolidating the remainder of the total workload will be offered exclusively by institutions of higher education. There is a differentiation of disciplines such as: compulsory (elective, according to the focus) and complementary (non-compulsory subjects). To subsidize the possible analysis was considered useful to describe the curriculum organization and groupings of content within the curriculum for graduation.

1.3 Profile of the Manufacturing Engineer

As usual definition used by both the American Institute of Industrial Engineering (aîîe) and by the Brazilian Association of Production Engineering (ABEPRO): "It is for Production Engineering design, implementation, improvement and maintenance of integrated production systems, involving men, materials and equipment, to specify, predict and evaluate the results obtained from these systems, using the expertise of mathematics, physics, social sciences, together with the principles and methods of analysis and engineering design. "(ABEPRO www.abepro.org.br).

The graduate course must have a solid scientific and professional general to enable him to identify, formulate and solve problems relating to the activities of design, operation and management of work and production systems of goods or services, considering aspects of human, economic, social and environmental issues, with ethical and humanistic vision in meeting the demands of society. Among these challenges, it requires the learning necessary to account for the productive management with environmental sustainability.

1.4 Components of the course curriculum of industrial engineering - research background

Furlanetto et al. (2006) conducted a search on specific core content of the courses of engineering and production among the topics selected were searched contents on Environmental Management and Ethics and Social Responsibility, on which it was found that "... only about a third of the courses have evaluated specific curriculum components to address them. " This research was performed in 48 courses and the sample for 25% of registered courses in the INEP in 2005 and the results, he says that "... we conclude that, in general, the selected topics are being treated very timid by the various courses that compose the sample in this research, leaving a first impression that courses through its curricular structure, are failing follow the rapid change that occurs with society in general and in particular the market.".

Also according to Oliveira et. al. (2005), currently there is a clear tendency to call Production Engineering "Full" ...) which has a comprehensive curriculum, capable of forming a professional with a holistic and highly prized position in the market today.

For this study checked the menus of all disciplines of the courses chosen by selecting those that have their menus of topics related to sustainability, environment and socio-environmental responsibility, whether they are directly related to the topics or adding a course. With this analysis it became possible to compare the institutions on the hours spent on the teaching of sustainability and the environment.

This information will be useful to examine how the university approaches to sustainability in their disciplines, the professional orientation and applicability of information provided to students, and diagnosis of the situation addressed by each institution, how is the integration of theory and practice of sustainability and environmental responsibility.

2. METHODOLOGY

Data collection consisted of visits to official pages on the Internet, both from INEP (www.inep.gov.br) as of Higher Education Institutions offering the course in Production Engineering and the Brazilian Association of Production Engineering - ABEPRO (www.abepro.org.br) as well as secondary data from other studies that have been developed with the same focus.

The procedures followed the order: first were investigated by the general information site for the INEP, subsequently, through access to official pages of the institutions surveyed, we analyzed each of the different curricular structures (curriculum, syllabuses and curriculum matrices) . A total of fifteen institutions were surveyed and the sample was comprised of five courses, representing each region. Possession of curricular structures and to evaluate how the courses of the different regions are dealing with some issues considered vital and current, due to legal requirements and market developments, we proceeded to measure the courses taking into consideration the following points: a) total course hours, b) distribution of hours of theory and practice, c) total hours in the subjects of sustainability and d) total hours of courses related to sustainability.

3. THE STUDY

3.1 Institutions and scenarios of the courses

To study the presence of the sustainability issue in training programs in production engineering, information was collected from five institutions of higher learning, as follows:
In the Northeast the Federal University of Pernambuco (UFPE) based in the city of Recife in Pernambuco state, which was founded in August 1946 through the union of the faculties of Law (1827), Medicine (1927) and Philosophy (1941) with School of Fine Arts (1932) and Engineering (1895), forming the University of Recife, the first university center of northern and northeastern Brazil. The course of production engineering at UFPE was authorized in June 1999 and the first entry in 2000. The course lasts 10 semesters hours and 3,600 hours, with 40 students per entry. For purposes of this study is called IES-northeast.

Among the institutions of the southern region was selected the Universidade Federal de Santa Catarina (UFSC) founded in 1960, headquartered in Florianopolis in Santa Catarina state. It is among the ten best universities in Latin America according to Webometrics Ranking of World Universities. He began acting in industrial engineering in 1969 with the Master's degree in industrial engineering and production management were created in 1979 and undergraduate courses in production engineering of civil, mechanical and electrical. The course is organized into 10 semesters with a schedule of 4500 hours, 40 entering students per year in annual two entries of 20 students. For purposes of this study is called IES-South.

In the southeastern region selected the course at the Federal University of Juiz de Fora (UFJF) which was founded in 1960 in the city of Juiz de Fora in Minas Gerais. The undergraduate program in industrial engineering was established in 2000 and is among the six courses that have obtained maximum concept in the National Examination Performance of Students (ENADE) in 2008. It is the first graduate course in Production Engineering to be certified by ISO 9001:2000 in Brazil. It has a duration of 10 semesters, with the total workload of 3,640 hours and receive 20 students per semester. For purposes of this study is called IES-Southeast.

The Midwest present the information from the Federal University of Goiás (UFG) which was founded in 1960 through the union of existing colleges, with headquarters in the city of Goiania in Goias state of the undergraduate course in Production Engineering was started in 2008, aiming to train more generalist engineers to the region. The course has face modality with annual intake of 50 students. The course has a duration of 10 semesters, has annual intake of students and a total of the 3,660 hours. For purposes of this study is called IES-West Center.

In the northern region known as the Amazon region used for studies of the University of Pará (UEPA) based in the city of Belem in Para state which had started its operations in 1994 from the amalgamation of the various state public colleges. The undergraduate degree in Production Engineering was established in 1998 and gained recognition in 2003. The university is constantly growing, and received 138 new teachers in 2008. With face modality, the course has minimum of 10 semesters and a total of the 3,600 hours. The course has an annual intake of 70 students, 40 students on the campus of the city of Belem and 30 students on the campus of the city of Redenção (Xingu region) For purposes of this study is called IES-North.

4.2 Presentation and Analysis of the data found

Data reveal that all institutions have reviewed the curriculum of the course of a set of production engineering disciplines with a focus on sustainability and other disciplines related to the topic.

Comparing the ratio of the total course hours and hours devoted to courses focused on sustainability and other related to the topic, according to the theoretical and practical, it appears that only the IES-South dedicated practice workload, as Table 1, prepared by Portilho for this article.

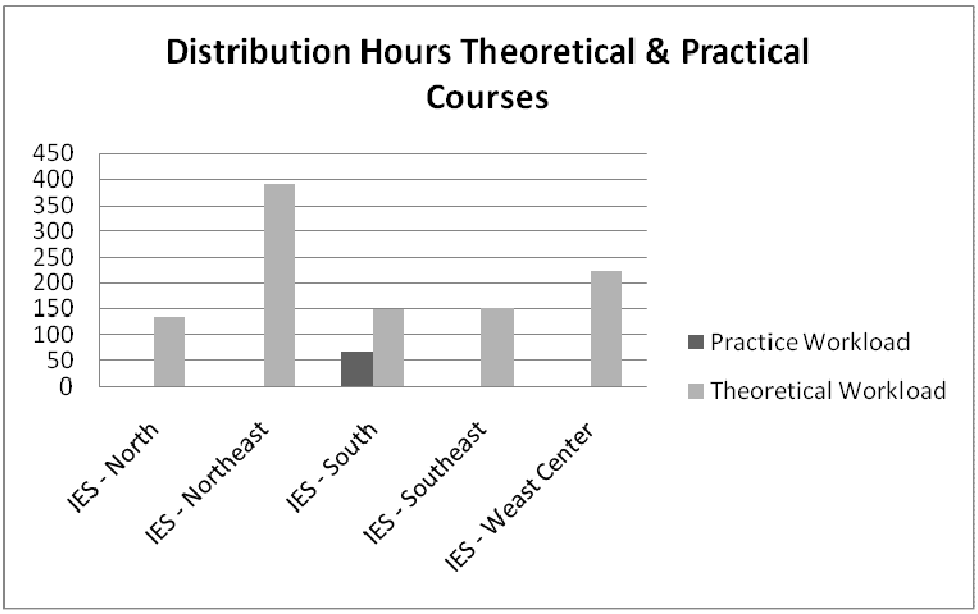

Table 1 - Distribution Hours Theoretical & Practical Courses

The higher education institutions surveyed have a coefficient of percentage between 4% and 11% of subjects relevant to the teaching of sustainability for a total of between 3,600 hours to 4,500 hours, as noted in Figure 1 constructed by Portilho for this article.

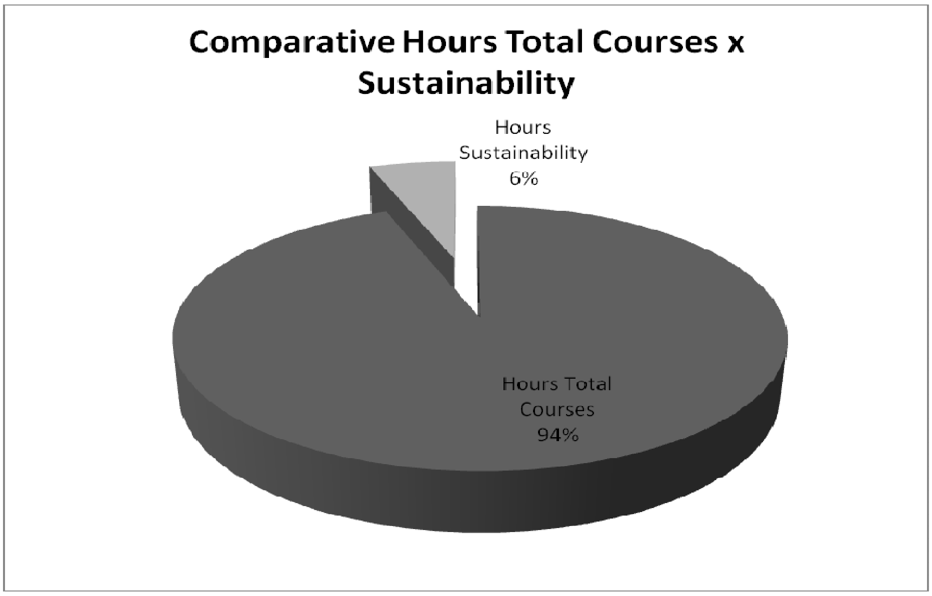

Figure 1 – Comparative Hours Total Courses x Sustainability

Concerning the location of the disciplines within the nuclei of basic content, professional and specific, we found most subjects located in the core content professional and mostly only with theoretical content.

4. CONCLUSION

This is a preliminary study for which he was selected and studied a small sample size, unrepresentative but indicative of other and urgent studies should be conducted on the curriculum of training courses for production engineers, considering that these are the contents that should make them capable of working in management in companies with competitive ability to produce with sustainability.

The data reveal that all the institutions studied devote hours of training to the subject, and the IES-Northeast has a superiority of studies related to the theme of sustainability within their graduation. As for total hours of classroom and practice for the teaching of subjects, it appears that only the IES-South intended hours in their curriculum organization for practical classes, which may reflect favorably on the professional activity of graduates.

About the theoretical and practical training, lack of practical approach to teaching sustainability within the courses Production Engineering, may be aggravating the moment in which we have instances of government and society in constant search for performance improvement over the environmental issues and sustainability.

These preliminary data allow us to conclude that institutions of higher education study, training of production engineers still do not address in his resume, as the key to sustainability and competitive.

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ANALYSIS OF INTERNATIONAL GRADUATE PROGRAMME STRUCTURES FOR ENGINEERING EDUCATION

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Abstract: This article traces the evolution of graduate study in Engineering in Ireland over three decades. Very few studies have shown the different norms and structures of graduate programmes in Ireland. In this paper, a review of traditional and structured PhD in terms of credit requirements and co-ordination structures is presented. The authors summarise the characteristics of graduate programmes in different universities in Ireland and compare these to those obtained in some of the leading international universities. The implementation of graduate programmes in Ireland is relatively recent and the structure of these programmes is still under development in the different universities. Plans for enhancement of graduate programs and the development of new initiatives to support graduate student academic and professional development are very important for the success of these programmes. The growth in enrolment reflects a broad diversity in background of students which will require not only increased financial resources but an adequate and sound organisational structure in order to move forward.

Keywords; graduate studies, engineering education, structured and traditional PhD.

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1. INTRODUCTION

The Doctorate Degree covers many fields of specialisation and requires a minimum of three to four years of study beyond the Bachelor's degree. Doctorates in Education, Science and Law are sometimes labeled Ed.D., Sc.D., Jur.D., but most doctorates are known as Ph.D. (Doctor of Philosophy) degrees. To obtain a Ph.D. degree, the university generally requires that a student fulfil some combination of the following (Fulbright, 2010; QAA.2001): Earn a certain number of credits in a required distribution of courses; Maintain an average grade second class honours degree; Pass a qualifying comprehensive examination after completion of the required courses; Pass examinations in one or more foreign languages; Present and defend a thesis which is the result of original research; and Pass an oral examination.

The European University Association completed a major research project on ‘Doctoral programmes for the European knowledge society’ in 2004/2005 (EUA a, 2005). This examined key issues concerning the structure and organisation, financing, quality and innovative practice in doctoral programmes across Europe. It involved six networks comprising forty-eight universities from twenty-two countries. There are six different types of recognised PhD degrees which are shown in Figure 1.

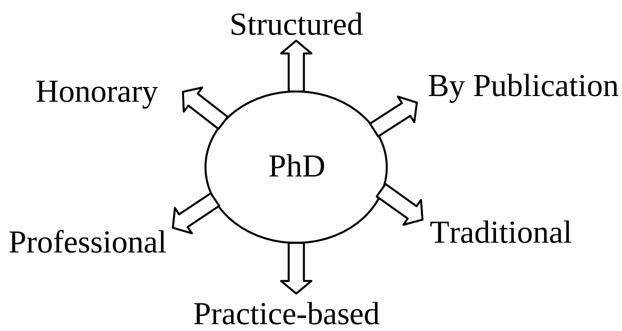

Figure 1: Typical PhD degrees (after NQAI, 2006; Scott et al. 2004)

Honorary doctorates are given for the exceptional contribution to society. With the exception of the honorary doctorate the major component of all doctorates is original research. Doctoral degree by publication is based on published work rather than a thesis. A thesis in combination with a creative work in the visual or performing arts is known as practice based Doctorate. Without a thesis, based on professional extra ordinary achievement, Professional Doctorates are awarded. In the traditional model, a PhD is awarded after defense of a submitted thesis without classification. Taught modules are generally not part of a traditional PhD model. Subject to its successful completion, the thesis can have a nominal value of 270 ECTS credits and requires at least 240 credits worth of advanced research at level 10 (Scott d. et al. 2004). There are a number of differences with respect to credit. Firstly, not all programmes are modularised and therefore are not credit-based. Secondly, where credit-ratings are specified, they differ between institutions and do not generally indicate whether all the credit is at doctoral level. Candidates who wish to pursue a structured PhD program would generally take not less than 300 credits. A research thesis equivalent to 270 ECTS credits and 30 ECTS credits for taking offered modules.

Regulations, Policies and Codes of Practice are different in different universities. Most programme structures are built in conjunction to the academic regulations for postgraduate degrees by research and thesis. These regulations are designed to safeguard both the academic standards of the University and the interests of individual students graduating from the university.

1.1 Advantages of structural PhD

Two criticisms of the traditional PhD in terms of its narrow focus are the limited set of skills acquired by PhD candidates and its isolation in general from the work place, see Scott, Brown, Lunt and Thorne (Scott et al. 2004). They and others (Green, Maxwell and Shanahan, 2001) (Scott D. et al. 2004; Maxwell et al., 2000, 2003) note the parallel growth in the Structural Doctorate and key shifts in the relationships between universities and the State and new understandings about knowledge (production/creation and form). Structured PhD programmes reflect on the range and nature of appropriate transferable skills and to reconceptualise students as people gaining work experience, and as early stage researchers. As a result students are involved in terms of professional work experience and are more oriented towards the workplace. Strong links with employers of graduates, who have a strong orientation towards the fields of education, can be achieved ensuring that research focus is now an active consideration. These partnerships include potential for mobility placements for staff and students, summer schools, joint course delivery, joint supervision, organisation of workshops and conferences

2. STRUCUTRE GRADUATE PROGRAMMES IN IRELAND

2.1 Higher Education Authority

There are seven universities in the Republic of Ireland. The University of Dublin, Trinity College, founded in 1592, is the oldest university in the country. The National University of Ireland (NUI) consists of four entities: National University of Ireland, Galway: National University of Ireland, Maynooth: University College Cork: and University College Dublin. The two newest universities, founded in 1989, are the University of Limerick and Dublin City University. There are fourteen Institutes of Technology, located throughout Ireland. These are government-funded institutions, offering courses at undergraduate certificate, diploma and degree levels. They also offer graduate programs, mainly by research. The Higher Education and Training Awards Council, under the National Qualifications Authority validate their qualifications. In addition to the publicly funded institutions, there are a number of independent third-level colleges, several of which offer graduate programs.

While Ireland has long enjoyed a high reputation as a culture centre, the government has also regarded investment in technology based higher education disciplines as key element in our national economic development. As a result of this investment, Ireland has developed a highly qualified workforce and has attracted considerable inward investment. Over the past 20 years, Ireland has grown into being a leading exporter of computer software, computer hardware, pharmaceuticals, and biomedical products. At the undergraduate level Bachelor's degrees consist of four years of study with this currently changing to a five year structure (as per Bologna guideline). This is followed by a range of graduate options, entry to most of which require a high level of honours Bachelors degree award.

PhDs in Ireland are generally by research and normally would be expected to take a minimum of three years. Students work under an academic supervisor and carry out research leading to the publication of a thesis that shows evidence of original work which presents a significant contribution to the related research area. Availability of places depends on the availability of an academic supervisor in the candidate's area of specialisation and funding availability (SFI, 2010). There is increased attention given by third level institutions, government agencies and research councils to research and train at doctoral level and the development of graduate schools in the context of developing a knowledge society. The Irish Universities framework proposal for the *'Reform of 3rd Level and Creation of 4th Level Ireland'* (2005) emphasises the need for new types of graduates at the 4th level (IUA, 2010). It illustrates this with reference to the need for a new model of structured PhD programmes with taught courses, training and formalised career development. These would be characterised by flexibility, responsiveness and inter-institutional and stakeholder collaboration. These proposals do not specifically address implementation methods for the Structural Doctorate but address the need for 'radical modernisation of PhD and post-doctoral training' to meet the needs of the knowledge society. These guides and the growth of Graduate Schools point to the ever increasing development and availability of structured PhD programmes in the future. In 2002/2004, The Irish Universities Quality Board carried out a research project on Good Practice in the Organisation of PhD programmes in Irish universities. The aim of the project was to improve the organisation and efficiency of PhD programmes in all Irish universities. At the outset of the project, it was decided to exclude non-PhDs and higher doctorates from the project (IUQB, 2004). The project led to the development of *'Guidelines for Good Practice in the organisation of PhD programmes in Irish universities'* in 2004. These address themes including administration, supervision, research project, induction and professional development, dissertation and examination. The Higher Education and Training

Awards Council (HETAC), in 2003, issued similar guidelines for post-graduate research, which included doctorates (HETAC, 2003).

2.2 Overview of national practice

Information provided by the universities to the Higher Education Authority does not distinguish between different types or titles of doctoral programmes (HESA, 2007). It should be noted that a number of institutions offer structured PhD programmes with substantial taught elements (e.g. PhD programme in Biomedical Sciences, Royal College of Surgeons of Ireland (RCSI) and in some cases, leading to named doctorates.

Entry requirements

There is some consistency in entry requirements for Doctorate programmes. These usually include specific performance in a Masters Degree and professional practice ‘at an appropriate level’ as determined by the institution offering the programme. For entry to some programmes, professional practice may not be required but can be taken into account. The academic qualifications required vary from 2nd class honours to masters. In exceptional cases, candidates who have not met all the relevant criteria may be accepted onto some programmes.

Specification of learning outcomes

The extent to which learning outcomes are specified or made explicit in programme material is mixed. It is possible that these are made more explicit in internal course approval/validation documentation or are inferred from programme aims and objectives. In some cases, they are clearly stated and published but in the majority of cases, this is not so. In some cases, learning outcomes are specified for modules only. The degree to which learning outcomes are specified appears to relate to the field of study/profession and general institutional practice. It would appear from the material available that the learning outcomes are at the same level as those specified in the descriptor for the Doctorate at level 10 in the national framework of qualifications.

In Trinity College Dublin, students participating in the structured PhD programme or seeking to transfer to the PhD register must participate in a set of modules agreed between the student, research supervision team, and the Postgraduate Director. Thirty units within the European Credit Transfer Systerm (ECTS) must be earned prior to confirmation on or transfer to the PhD register. The normal distribution of credits is as follows: 5 ECTS in Research Methods; 5 ECTS in Introduction to Statistics and 20 ECTS which can be in the form of directed studies modules, from the pool of modules available in the School, or from other externally certified taught modules (such as from partner universities or summer schools). In University College Dublin, a Doctoral Studies Panel is appointed normally in early first year. The purpose of this Panel is to support and enhance the supervisor-student relationship, to monitor progress during the course of doctoral studies and to provide advice and support both student and supervisors. Research and professional development planning is an integral part of this Structured PhD programme. The purpose of such planning is to ensure that student’s work is clearly focused on achieving research and professional development goals. This will play a major part in informing the trajectory of PhD research, training and development. This Structured PhD operates within a credit-based framework, with one credit corresponding to 20 to 25 hours of total student effort. If undertaking a 3-year PhD programme, student can earn 30 credits by attending modules that develop academic and transferable skills. There are structured PhDs in Bioinformatics and Systems Biology and Software Engineering at University College Dublin. In the University of Maynooth, for humanities e.g. Economics, geography and business there are compulsory structured PhD but, there are no compulsory structured PhD programmes for technology related awards. There are however optional graduate modules available. In Dublin City University (DCU) there are structural PhDs for humanities and business. In engineering, DCU partakes in two national level graduate school programmes, one in photonics (INSPIRE) and another in software engineering (LERO) funded through government PRTLI programme. St. Patrick's College Drumcondra (SPCD) has two Faculties' humanities and Education. Since 1993 it has been a College of Dublin City University and all courses are accredited by the university. Discussion is underway at present with DCU as part of SPCD's planning and foresight process with the possibility of more formal links in the delivery of graduate programmes. To this end, the SPCD-DCU linkage management committee has as one of its functions facilitation of joint programmes and central among these are structured graduate programmes, in particular in education and within the Education-Humanities spectrum.

3. INTERNATIONAL GRADUATE PROGRAMMES

3.1 North America

The Research Doctorate represents the third and highest stage of higher education in the United States and may be awarded in academic disciplines and some professional fields of study. This degree is not awarded by examination or coursework only, but requires demonstrated mastery of the chosen subject and the ability to conduct independent, original research. Doctoral programmes require intensive study and research in at least one subfield and professional level competence in several others. Following a series of research seminars designed to prepare the individual research proposal, candidate examinations (covering at least two subfields in addition to the field of research focus, one of which must be in a subject outside the doctoral student's own faculty but related to his/her research). If the candidate examinations are passed at a satisfactory standard (excellent or higher), the student is advanced to candidacy for the doctorate and selects a research committee of senior faculty who will approve the dissertation topic, monitor progress, and examine the student when the research is finished. The conduct of research and preparation of the dissertation can take anywhere from one to several years depending on the chosen subject, available research funding, and the location of the research. When the dissertation is finished and approved as a document by the chair of the research committee, that individual convenes the full committee plus any outside faculty and public guests and presides over the candidate's oral defence of the dissertation. A unanimous vote of the research committee and examiners is generally required to award the doctorate. Most doctoral degrees take at least 4 or 5 years of full-time study and research after the award of a Bachelor's degree or at least 2 to 3 years following a Master's degree. The actual time to obtain the degree varies depending upon the subject and the structure of the programme.

The University of Massachusetts Medical School (UMMS) is nationally ranked for its excellence in research, health care and health sciences education, while Worcester Polytechnic Institute (WPI) is ranked as one of the best engineering schools in the Northeast. Capitalising on these factors, the Graduate School of Biomedical Sciences (GSBS), UMMS and WPI initiated a joint PhD program in Biomedical Engineering & Medical Physics in 1996. This formal program employs the advanced technical expertise of engineering and medical faculty and utilizes the experience and resources available from a public research university and a private institute of higher education to train students in the application of engineering to medical research. Graduates of the joint PhD program are prepared to work as faculty of academic institutions or as employees of the growing medical device and biotechnology industries that have seen major economic growth in Massachusetts. Due to the highly specialized nature of the program, it is open only to those applicants who already have an undergraduate degree or a strong background in mathematics, physics or engineering. Applicants are also expected to have had one semester of organic chemistry and a full year of biology. Course of Study Prior to completing qualifying examinations, students spend approximately two years taking advanced biomedical science and engineering courses at UMMS and WPI. Flexibility is allowed for specific course requirements based upon students' backgrounds and areas of interest. Since the two campuses are only ten minutes apart, laboratory rotations, courses and seminars can be taken simultaneously during the first two years. The joint program also offers shared courses and options to do thesis work at either institution. Committee structure, qualifying examinations and dissertation defences follow the same basic format currently used by the GSBS, with the exception that all committees are made up of representatives from both institutions. The program is for full-time students, for a minimum of at least three years (residency requirement). Approximately 90 credits of graduate-level courses and thesis research are required, and the PhD in Biomedical Engineering is awarded jointly by WPI and UMMS, with the appropriate designation on the diploma.

3.2 Europe

There is a range of models of graduate schools in the UK and other European countries. EU funding for inter-institutional doctoral programmes has recently been made available, Erasmus Mundus (EACEA, 2009). Since the 1990s most UK universities have structured their doctoral provision around graduate schools, although the nature and remit of these vary widely (UKCGE, 2004). In the UK, graduate schools tend to be a governance structure that spans the institution or individual faculties and schools. They facilitate the strategic management and coordination of postgraduate provision and provide a means of representing postgraduate interests at an institutional level. In many cases, graduate schools cover both doctoral researchers and taught postgraduate students. Other models within Europe include ‘doctoral’ or ‘research’ schools focusing on specific research themes, often across a number of institutions, where membership and access to facilities or resources might be restricted to select groups of doctoral candidates, such as the German ‘excellence initiative’ (DFG,2009). At a European level, the European University Association’s Council for Doctoral Education, launched in 2008, was set up to support discussion among European universities about the development of doctoral programmes (EUA b, 2009).

Bologna Third Cycle

The issue of doctoral studies is under continual discussion in the Bologna process. The Bergen communiqué, June 2005, called for the ‘further development of the basic principles for doctoral programmes, to be presented to Ministers in 2007 (Bologna process a, 2005). The Bologna seminar on ‘Doctoral programmes for the European knowledge society already took steps in this direction in that it reached agreement on ten basic principles that should underpin further considerations of the key role of doctoral programmes and research training in the Bologna process (Bologna process b, 2005). The Bergen communiqué also states that doctoral level qualifications need to be fully aligned with the EHEA overarching framework for qualifications using the outcomes-based approach’. A declaration on professional higher education was made by rectors conferences and associations representing higher education institutions outside the university sector to the Bergen Ministerial meeting (2005). This emphasised the importance of this strand of higher education and of the professional doctorates. The implementation of the Bologna protocol in the European Union has set new goals for the whole higher education system as: (a) a quality assessment for university courses; (b) a framework for the exchange of students and academics; and (c) an opportunity for changing the teaching/learning procedures and methodologies (Teixeira et al., 2007). The doctoral cycle of the Bologna process (Bologna Process third cycle, 2008) endorses the development of appropriate organisational structures in the form of doctoral, research or graduate schools. Organisational structures chosen must demonstrate added value for the institution, in particular in seeking to: counteract the isolation of the young researcher from other disciplines, or from the larger peer group, or the larger scientific community; establish transparency of expectations, quality and assessment standards (supervision etc); and create synergies regarding generic skills training (at institutional or at interinstitutional level). The structured PhD programmes which are increasingly a feature of doctoral education in the UK, Ireland and Europe generally respond to criticisms of the traditional PhD programmes and meet new demands. It is envisaged that the European Community will as a matter of policy continue to provide finance for co-operative research and for staff and student mobility across national boundaries (McCABE, 1998). Many departments of engineering will experience significant changes in attitudes to the industrial world and to course structure to meet student mobility if departments are to fully meet the challenges and opportunities posed. The provision of adequate financing will be a permanent problem and more use will be made of industrial sponsorship, research contracts and EC research contracts. Programmes of instruction, even in the same country, will no longer be of the same invariable monolithic structure and the division between professional and sub-professional engineering courses will no longer be as sharp or clearly defined as in the past. Co-operation and interaction with institutions in other countries in research and teaching together with staff and student mobility will contribute significantly to the interest, efficiency and value of the schools of engineering at the turn of the century.

4. CONCLUSIONS

Advanced training is becoming an increasingly important element in graduate research. The intention of such training is to produce researchers with a broader approach to problem solving and more attuned to later career opportunities within the relevant industrial and business sectors. Graduate training involves additional educational and training elements which develop advanced knowledge, skills and competencies required for successful original research. Such training supports the acquisition of both significant disciplinary learning and more generic transferable skills, while also making students aware of possible opportunities to commercialise and further their research. Generic skills of advantage to the graduate trainee include technical writing, presentation, tutoring and demonstrating, research design, qualitative and quantitative research methods, operations research, programming, commercialisation, and research ethics courses. The structure of Professional Doctorates varies significantly depending on the discipline and/or professional field relevant to the programme. In general terms, programmes include substantial taught elements (in some cases with some overlap with Masters programmes) which can be transdisciplinary as well as disciplinary, project work and a thesis. They can be designed to allow for flexible, part-time delivery and a mix of taught, research and thesis components. Block mode delivery of modules in shorter time periods has proven most flexible for various institutions, postgraduate students and outside interested participants. There is variation in the number of taught modules and project work involved and in their share of the overall doctoral programme. Although the measured in terms of credits and duration varies from case to case, coursework and thesis form a part of every programme. The need to raise Science and Technology (S&T) knowledge and skills in order to serve national educational, economic and entrepreneurial goals requires the implementation of a coherent structured PhD. By stimulating interest in S&T and by increasing student participation in traditionally problematic subject areas, future employability and S&T literacy can be enhanced. A multidisciplinary approach will enable graduates to address problem solving within real-life situations and more readily identify more optimised problem solutions. Structured PhD programmes are increasingly common across Europe as are collaboration between institutes of higher education and research institutes in doctoral training.

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Research on student understanding as a guide for the development of instructional materials in introductory engineering courses

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Abstract: At Hamburg University of Technology, we are engaged in (1) investigating student understanding of fundamental concepts in electrical and mechanical engineering and (2) using the results from this study to guide the development of instructional materials. In this paper, we present methodology and illustrate the process of research and curriculum development with an example from an introductory Engineering Mechanics course. Our analysis suggests that when combined with active learning techniques, instructional materials developed on the basis of research on student understanding can improve student learning.

Keywords: *curriculum development, mechanical engineering, statics*

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1. INTRODUCTION

While the challenges for society in the 21st century require future engineers to obtain a broad set of skills, a thorough understanding of basic science and engineering concepts will remain one of the core objectives of engineering education. It is widely known that for many students, typical introductory courses are not successful in achieving this goal. Changes in the instructional settings, such as incorporating more active learning formats, seem to have a chance at enhancing learning outcomes, but effective instruction in introductory science and engineering may require more than the mere adoption of a different learning format. Educational research based in these disciplines has identified specific conceptual and reasoning difficulties that often prevent students from developing a functional understanding of many of the topics taught in these courses. There is evidence that instructional materials that foster active learning and take into account such difficulties are more likely to improve student learning. At Hamburg University of Technology (TUHH), we are engaged in (1) investigating student understanding of fundamental concepts in electrical and mechanical engineering and (2) using the results from this study to guide the development of instructional materials.

A new development in Engineering Education in Europe is to deal with students' subject-specific misconceptions and misunderstandings. This development follows similar approaches which are increasingly used in physics education. About five years ago we began a program at TUHH to adapt the approach to engineering education in Germany. Our focus has been on the three introductory courses in mechanics, electric circuits and thermodynamics. The present article is concerned with our discoveries of student difficulties with statics concepts in mechanics which we obtained through analysis of assessment tests and interviews with students.

Our program consists of roughly three broader steps: First identifying the difficulties, addressing the difficulties through interventions and lastly evaluating the success of the intervention. To identify student difficulties we begin by analyzing students' written responses in homework assignments or examinations, including results from assessment tests. Subsequent to this analysis we invite students for an interview in which we ask them to analyze or solve problems involving concepts that our analysis flags as potentially problematic. In this article we will show how this two-step procedure identified a student misconception related to the static equivalence between forces and moments that appears to have been overlooked by previous research. Based on a deeper understanding of student difficulties we currently develop *worksheets* that address the identified difficulties. These worksheets are designed to be used in weekly collaborative-group tutorials. The success of the intervention is evaluated in a twofold manner: first through standard assessment tests; second through an assessment of student performance on exam questions which have been specially designed in light of the identified misconception.

The remainder of this article is as follows: In section 2 we provide additional details regarding our local environment and our specific methodology. In section 3 we describe particular misconceptions regarding static equivalence, in particular between forces and moments, and detail how they came to be identified. A description of the intervention is given in section 4, and the results of our assessment are provided in section 5. We conclude with a summary in section 6.

2. CONTEXT AND METHODS

Hamburg University of Technology (TUHH) was established in 1978 and currently has a student body of about 5000. Although it draws students mostly from the greater Hamburg area, and the primary language of instruction is German, it is internationally oriented with an increasing number of English language programs. TUHH is primarily an engineering school offering undergraduate and graduate degrees in civil, electrical, mechanical and chemical engineering among others. Students admitted to the TUHH usually have the *Zeugnis der Allgemeinen Hochschulreife* which is roughly equivalent to the *International Baccalaureate* or the English *A-Levels*. Some students will additionally have completed a three-year apprenticeship.

Our research group was established six years ago within the Institute of Mechanics and Ocean Sciences. Our focus in the project described here is on students pursuing a degree in mechanical engineering or students from other fields who require the four-semester *Mechanics* sequence. The first semester of the *Mechanics* sequence covers Statics. It is the Statics portion of the Mechanics sequence that we address in our study. Since 2005 the *Force Concept Inventory* by Hestenes et al. (1992) has been given as a pre-test prior to the start of instruction. At the end of the first semester the *Statics Concept Inventory* by Steif (2005) has been given as a post-test. To date slightly over 1200 students have taken these exams at TUHH as part of our study. Since the summer of 2009 we have also been interviewing students to identify conceptual shortcomings.

Based on an analysis of results from the Statics Concept Inventory (SCI) we identified topics which students appear to struggle with. The persistently most difficult concept covered by the test is that of *static equivalence*, as measured by a subset of three (of 27) test items. To further explore this apparent conceptual shortcoming we conducted interviews with students from the mechanics course in the summer semester of 2009. The interview procedure and questions were designed based on assessment questions and the content of course lectures. Interviewees were self selecting – during the course of the semester students were asked if they were willing to be interviewed. Of the roughly 400 students who took the course, ten students indicated a willingness to participate in our interviews, and eight eventually came to the interviews. The interviews were conducted after the semester was over, but before the final exam was given. One incentive for students to participate in the interview was the potential for it to help with their exam preparations. All of the participating students agreed to provide us with their student IDs. This information enabled us to gauge their relative standing in the class based on the already given pre-test (FCI) and post-test (SCI). The eight students were among the more highly achieving students of the class, all but one were in the upper half of their class, four of these were in or above the 90th percentile as measured by the SCI. Because we were not involved in writing or grading the course examination, we could be free (*i.e.*, unbiased) in how we posed our questions, and the students could also answer somewhat more freely as misconceptions would not be held against them. All interviews were recorded with a digital video recorder.

While the interviews did not adequately sample the class, this was not their purpose. Rather, our goal was to use the interviews to identify misconceptions that students appeared to have. Our hypothesis was that a misconception that emerges consistently in interviews with even a few students is likely to be more widely shared. Put another way, one may ask what is the probability that among eight - admittedly self-selected - students a misconception emerges that is otherwise absent from the wider student body. Given that the students we interviewed ended up being relatively high achievers, it would seem even more likely that the misconceptions which they held would be reflected more broadly. But even to the extent that the misconceptions we identify turn out to be isolated, many of our points address methodological issues and hence remain germane to the larger questions in engineering education to which our study addresses itself.

Figure 1: At the conclusion of the interview students were given the opportunity to hold the imagined slider-and-beam to test their understanding of the concepts explored in the thought-experiment part of the interview.

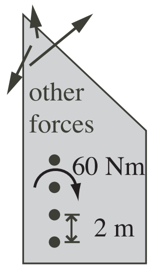
Each interview consisted of two parts. The first part involved having the students participate in a thought experiment. They were shown an object consisting of a moveable Γ-shaped object (slider) mounted on a beam that was assumed to be weightless (Figure 1). The slider could be mounted in one of two ways: with the overhanging branch directed along the beam away from, or toward, the person. We will refer to this object as *slider-and-beam*. The students were asked to imagine holding the end of the beam in their hand and to predict whether they would feel a difference in their hand while holding the slider-and-beam as a function of the orientation of the slider. They were then asked to explain their prediction using concepts developed in the mechanics course.

In the second part of the interview the students were asked to answer one question from the SCI and another question similar to the SCI question, but with an answer (tailored to probe what we anticipated to be a major misconception) added (Figure 2). In both parts of the interview we asked the students to think 'out loud' as much as possible so that we could gain insight into the root of any misunderstandings.

A 60 Nm couple acting clockwise keeps the member in equilibrium while it is subjected to other forces acting in the plane shown schematically at the top. The four dots denote vertically aligned, equally spaced points along the member.

Assuming the other forces stay the same, what load(s) could replace the 60 Nm couple and maintain equilibrium?

Mark all possible answers.



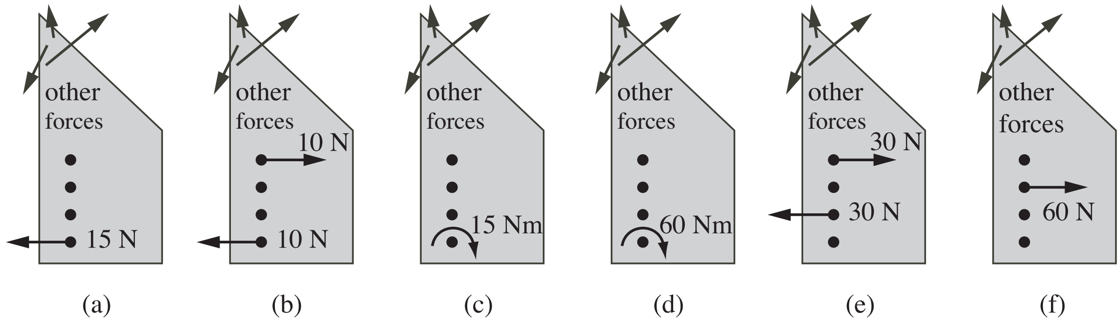


Figure 2: Example of an SCI-like interview question designed to explore the student misunderstanding that forces and moments are interchangeable.

3. MISCONCEPTIONS IN ENGINEERING STATICS

The answers and explanations received from the interviewees in relation to the first task, the slider-and-beam thought experiment, revealed various difficulties associated with identifying a specific system to be analyzed and recognizing the implications of a specific choice of system. Students generally were able to answer correctly that the beam with outward-directed slider would 'feel heavier' than the inward-directed case. They also could explain this in terms of the change in the center of mass of the system consisting of the beam and the slider. We then asked the students to consider their answer if the beam alone were chosen as the system to be analyzed, as this was the object that communicated the change in the orientation of the slider to their hand. From this point of view, or choice of system, the students had difficulty in identifying a reason as to why the situation should depend on the orientation of the slider. Some students, who realized that their answer should not depend on the choice of the system, then changed their initially correct answer and said that the orientation of the extension would not be felt by the person holding the beam.

Through our analysis of student responses in both parts of the interview we identified the following misconceptions:

- belief that forces and moments are interchangeable;
- failure to recognize that forces as well as moments are interactions between two bodies;
- belief that the point where a couple is applied will be a fixed point in an ensuing rotation caused by the couple;

The first point has been discussed by Newcomer and Steif (2008), and (in a somewhat different context) by Ortiz et al. (2005), the second by McDermott et al. (1994). To our knowledge the third point has not previously been identified.

4. INTERVENTION

Starting in the Fall of 2009 we developed weekly worksheets modeled after the *Tutorials in Introductory Physics* by McDermott et al. (1998), which are now widely used in Physics instruction. These worksheets included problems and exercises, some of which were designed to address specific difficulties that our research had previously uncovered. The other major difference between these worksheets and traditional exercises given in engineering courses is the emphasis on qualitative understanding rather than quantitative problems often mastered through having memorized algorithms.

Hannes: *"System* II *is equivalent to system* I. *Remember,* $\vec{M} = \vec{d} \times \vec{F}$. *Hence, a moment of* $12\,\mathrm{Nm}$ *with respect to* P *can be replaced by a* $3\,\mathrm{N}$ *force,* $4\,\mathrm{m}$ *to the right of* P."

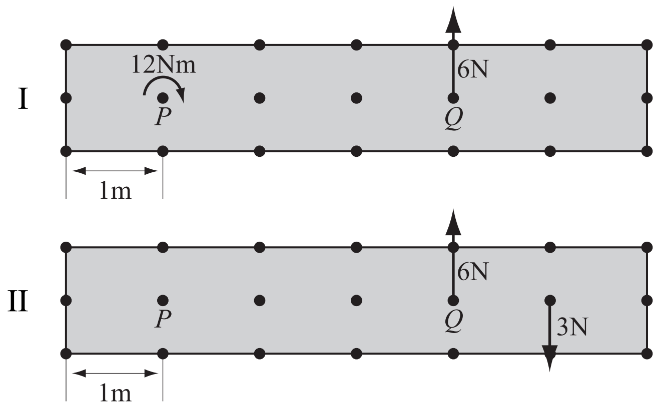


Figure 3: An example of material for a qualitative question designed to address misunderstandings of interchangeability of forces and moments

An example of this type of question is provided by the situation shown in Figure 3. Students, organized in small groups, are then asked to answer three questions.

a. Do you agree with Hannes? Justify your answer.

b. Compare the resulting forces in systems I and II.

c. Compare the resulting moments relative to point Q for both systems.

5. ASSESSMENT

We attempted to measure the effectiveness of interventions by comparing pre- and post-test data for the past five years. Only one of these years, the last, incorporated the intervention described above. Of the five years, the year 2009-2010, which had the benefit of the intervention, scored the highest on the SCI (see Table 1). This year also had a relatively lower pre-test (FCI) score, indicating that higher achievement was not likely attributable to initial conditions.

Because the instructional sections on static equivalence (included as parts of three subsequent worksheets) were most directly affected by the outcomes of the interviews, we specifically looked at the average post-test results of the three test items comprising the static-equivalence subsection (stat-eq) of the SCI (see last column in Table 1). In contrast to the overall post-test results, student achievement on the subsection was by far the highest in the 2009-2010 cohort, even if compared to the relatively strong result of 2005-2006.

Year	Instructor	FCI (pre) [%]	SCI (post) [%]	stat-eq [%]
2005-2006	A	50	42	17
2006-2007	B	45	36	12
2007-2008	A	51	30	11
2008-2009	B	49	29	13
2009-2010	B	47	43	27

Table 1: Summary of FCI pre and SCI post-test results over the last five years, as well as post-test results of static equivalence subsection of SCI.

While these results are encouraging, there are at least two additional factors which could explain the relatively good performance 2009-2010 semester students. First, in 2009-2010 the curriculum was slightly changed, with the net effect that student contact hours with a teaching assistant effectively doubled. Second, instructor B (Table 1) who taught the course in 2009-2010 followed a format that was introduced by instructor A in 2007-2008 to incorporate active learning, and which instructor B had followed for the first time in 2008-2009. Hence additional contact with teaching assistants and improvement in the basic instruction, including a mastery of active learning techniques, could provide alternative explanations for the remarkable gains in 2009-2010. We believe all of the above likely played a role.

6. SUMMARY AND CONCLUSIONS

A three step program has been implemented to advance engineering education at the TUHH. The steps consist of identifying student difficulties or misconceptions, designing interventions to address these misconceptions, and developing methods to explore the effectiveness of such interventions. In this paper we focus on a description of this program as applied to a first semester mechanics course taken by incoming engineering students. Interviews identified the following issues:

- belief that forces and moments are interchangeable;
- failure to recognize that forces as well as moments are interactions between two bodies;
- belief that the point where a couple is applied will be a fixed point in an ensuing rotation caused by the couple;

While the first two points are generally well recognized, the third has to our knowledge not previously been identified. The use of new learning material, specifically designed to address these student issues, and its implementation in an active learning environment show signs of significantly improving student outcomes.

Acknowledgements This research was funded by a grant from NORDMETALL. We thank the instructors and assistants of Mechanics I for their cooperation and contributions to this study. We would also like to thank the two reviewers for their thoughtful and encouraging comments.

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PROJECT TEACHING IN BIOMEDICAL ENGINEERING

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Abstract: Bologna strategy endures and makes teaching a new challenge. Student-based learning is difficult to achieve especially when their background is based on a knowledge learning bases.
This paper aims at discussing a new approach to the teaching of Biomaterials and Electromagnetism, using a student centred competence based learning. A semester project was proposed involving these two units in which students had to comprehend, do a critical analysis and propose improvement solutions of several (one each group) biomedical devices. The students rapidly bonded to the idea as the theme chosen would directly concur to their future work. They were also encouraged to draw a project plan and in every class a situation status would be made with each group and the developments achieved during the respective week analysed. From this brainstorming new ideas and solid solutions were drawn. Students learnt that two, at first, completely different classes had more in common than expected: both units were well integrated in the project, which gave them the sense that biomedical is really a wide spectra engineering and of what they will get in touch in “real life”, moreover they learnt that most of the time the first choices, although wrong, can make them go a long way. The outcome results of this project were fantastic as 14 of 15 students were approved. In fact the quality and solutions achieved at the end of the project overcame our expectations not only for the solution itself but also, and probably more important for the students’ enthusiasm and commitment.

Keywords: project teaching, engineering education, interdisciplinary.

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1. INTRODUCTION

The not so recent reform of the European Higher Education System, imposed by the Bologna agreement and the Bergan Communique, is having a profound impact both on organisations and institutions, where it is required to implement learning outcomes and assessment policies for all curricula (Bergen Communique, 2005; Bresciani,2006; Hubball and Burt, 2004; Hubball and Gold, 2007). Furthermore, these strategies also imply a different approach to teaching, going from a teacher centered to a student centered learning.
Portugal's case is no different from many others; teachers urged to understand the new developments and tried to effectively change the teaching methods. Nevertheless, the students’ resistance to new methodologies is high.

In accordance to the equality and mobility required by the Bologna agreement, in the academic year of 2006/07 a reorganisation of the Portuguese National Higher Education System took place. The most visible effect of the reorganisation was the change in duration of the Engineering undergraduate degrees from 5 to 3 years.

Although this new structure brought Portugal close together with the undergraduate degrees from the northern Europe, promoting mobility of students and teachers around the Higher Education Institutions in Europe, as a Latin country it has had a major drawback in the community acceptance of these “new” 3 year graduate students. Moreover, the 12 years of undergraduate teaching that precede the Higher Education is, still today, teacher-centered. Therefore, first year students are not ready to endure a student-centered course as they were not prepared in such way. They lack autonomy, will, self-confidence, but also oral presentation, group organisation and debate skills.

This is a drawback in the implementation of the student-centered learning strategies in the first year and teachers face students' lack of motivation and higher abandon rates, therefore taking the problem forward to the 2nd year.

Engineering teaching in Portugal, as in many other European countries, had a traditional teaching model – teacher-centered learning - with the teacher passing the necessary information in lectures and assessment based on end of term exams. Laboratory work was also performed based on a protocol follow up.

Since most Universities maintained the 5 year degree (Integrated Master), as they were obliged by the Portuguese Engineers Association, the educational methodologies had very little changes.

The importance of teaching best practices, especially in the cases where a 5 year engineering course are now reduced to 3 years is of utmost importance.

In order to obtain both the theoretical as well as the practical knowledge, essential in engineering, student-based learning based on inquiry-based teaching and research-led-teaching are methodologies that are being successfully tested in the engineering field.

Biomedical engineering is a relatively recent scientific field that has grown into an engineering degree in recent years. This degree is of broad spectra comprising areas of interest such as biology, medicine, materials science, and electronics, among others. The strategies adopted to overcome the clear differences in medical and engineering areas were having a straight collaboration between medical and engineering institutions and having different background teachers preferably with interconnecting research areas.

2. CASE STUDY

The Biomedical Engineering degree in Escola Superior de Estudos Industriais e de Gestão (ESEIG) had it's beginning in October of 2006. The degree resulted from a collaboration with ESEIG and ESTSP (Escola Superior de Tecnologias da Saúde do Porto) – both schools from Instituto Politécnico do Porto (IPP).

Originally, the degree's main objective was to suppress the gap that effectively exists between the two already referred areas namely in what medical machines (both medical instruments and medical devices) are concerned.

Looking at the program of the 2nd year of BsC in Biomedical Engineering one could imagine, at a first glance, that the student-centered teaching would be difficult and that the interdisciplinarity found was close to none. Nevertheless, when teaching Biomaterials and Electromagnetism some baselines that are common could be found. Furthermore, in a 3 year degree course it is of utmost importance to provide students with tools that they can and will use in a future job, instead of just turning them into information archives. In this way and trying to approach teaching to the new paradigm, an interdisciplinary assignment was proposed.

1.1 Study group

To comprise the assignment objectives a group of students of the 2nd year of Biomedical Engineering was used. This group consisted of 15 students distributed according to the following table:

Students	1st time enrolment	2nd time enrolment
Female	10	- - -
Male	3	2
Total	13	2

Table 1 - Study group distribution.

The students had a homogeneous distribution, with an 87% 1st time enrolment rate. As they were all 2nd year students, they were well acquainted which led to a better work relation both inside and outside the formed teams. Groups were organized by the students under the guideline of a maximum of two. The goal was to maximize productivity but also to hold the students accountable for their choices.
The project themes were randomly sorted from a previously given list.
Different themes and groups resulted in a variety of different approaches led by different group methodologies. This process was weekly supervised.

1.2 Interdisciplinary Assignment

In order to fulfil the assignment students had to analyse a biomedical device; each team had a different biomedical device. The biomedical devices to be studied were:

- Responsive drug delivery system;
- Pacemaker;
- Artificial heart;
- Dialysis system;
- Neuromuscular functional simulation;
- Cardiopulmonary bypass;
- Biomedical micro-machines.

In this process, students were required to:

1. Separate the main components and their function in the device;
2. Comprehend device interactions both with host and environment;
3. Understand device's biocompatibility problems, gaining knowledge of devices' pros and cons, in this particular area;

4. Improve the device and compare it with the original solution (no restrictions were made on this – the teams could minimize an existing problem or limitation, optimize the process or the use, find a way to reduce costs, etc).

It was made very clear to the groups that a critical, scientific, engineering analysis was expected of them. An adequate state of the art with a good theoretical background and a solid bibliography and reference articles (from reliable sources) was necessary and it would be reflected on their final grade.

Both Biomaterials and Electromagnetism courses had a percentage of their global evaluation resting on this interdisciplinary assignment but students were warned that this assignment was truly interdisciplinary and the areas of expertise ranged far from just these two areas. Groups were advised to work on the assignment overlooking that it was proposed by those two courses and search for the necessary information in all areas necessary to achieve the proposed objectives.

1.3 Learning outcomes

As it was already stressed, within three years, students have to be prepared to enter the market, therefore the educational system has to provide the students with more than just theoretical knowledge, especially in their area of expertise - Biomedical Engineering.

Nowadays, to form engineers it is necessary to move away from a conventional, pre-Bologna, teacher-oriented learning system where the learning outcomes were comprised mainly of theoretical knowledge. Now the learning outcomes have to ensure that more than just theoretical knowledge, the students have to learn how to search for knowledge (**to know how to know**) and most importantly the students need to know how to approach and solve real life problems and situations (**to know how to do**).

The assignment aimed at achieving these goals; more than just learning the theory, students acquired skills they can use throughout their working lives:

- to search for the necessary knowledge using reliable sources;
- to face a real life problem approach and critically analyse it, using both scientific knowledge and common sense to propose an improvement to the original problem.

These assignment outcomes go further than science itself, students were expected to plan forward, improve their group skills, write a coherent report and do a short presentation, once all of these parameters were also to be evaluated.

1.4. Methodology

In order to achieve the goals a clear methodology was exposed to the students in the first lesson. Furthermore, this was given in writing and posted in the courses webpage (webcourse).

Goals, check points and strict deadlines were proposed as well as a detailed list of requirements to be fulfilled.

A review article was supplied to all groups, to work as “kick start” to their biomedical device and in two weeks time a “game plan” should be uploaded in the webcourse.

One week after the deadline for the “game plan” there was a first meeting with the groups, this was the first checkpoint. The agenda, for each group, was to discuss their specific device selection, their planning and their reference list.
Each group meeting was carefully planned by the teachers and a scheme of green, yellow and red cards was taken. After each meeting the groups were told about their situation, whether they were going on the right track (green), if there were still some faults they had to mend (yellow) or if their plan made no sense (red), in this latter case the groups were given an opportunity to redo their “game plan”.
This was a very important checkpoint because it helped groups stay focused without interfering with their independence. In fact, the whole idea of such an early check was that their track was only half drawn (let’s not forget that they were 2nd year students) and therefore on the meeting only ideas were debated and some questions on the background of the idea were raised.

Checkpoints were set more or less regularly depending on the groups’ progress, always having in mind not to lead them but to actually make them think about the track they were following. Nevertheless, an “open door” policy was implemented, being this a student-based learning.

In order to facilitate the final report evaluation a master report form was given to the groups in order to insure that some of the requirements of the assignment were fulfilled. This report was to be uploaded in the webcourse.
The final checkpoint was the presentation. Groups had to present their work and should stress the following points: Device; Properties; Interactions; Comprehensive analysis; Improvements/solution.

3. RESULTS AND DISCUSSION

The results obtained were very positive; more than just achievement of good results, the students devoted the necessary time and energy on the assignment as they felt that the themes were adequate to the biomedical engineering area of expertise and that the learning experience was valuable and worth the effort. This was shown early on by their enthusiasm while researching information.
All groups uploaded and presented their assignment on schedule.
However, the students' enthusiasm didn't always resulted in good planning or even a good definition of what was important and what wasn't which was evident in their first checkpoint.
The results for the first checkpoint were given in terms of a scheme of green, yellow and red cards defined above. These results are presented in the following chart (Figure 1).
Only one of the groups that received a red card shown an evidently lack of effort in producing their “game plan”, the other groups were overwhelmed by the amount of information that they found and had difficulties choosing a specific biomedical device and therefore weren't able to define an appropriate planning. These groups had another opportunity to redo their “game plan” and did so but were effectively behind in the timetable they had to fulfill all the requirements.

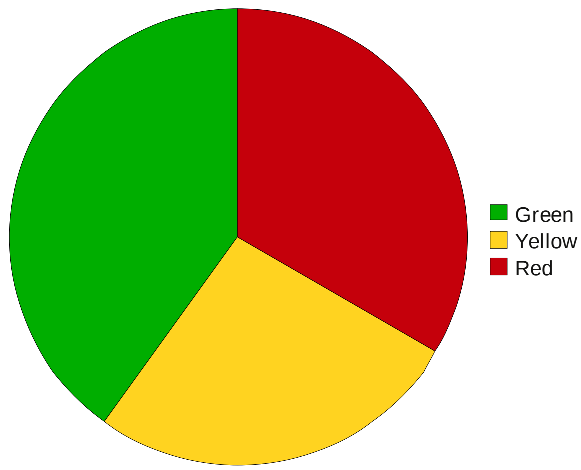

Figure 1 - First checkpoint grading.

Groups that received a green card went on according to initial planning which produced better organized reports with more information relating to each subject. They were not necessarily the ones with better information, nevertheless had some of the best grades, as one would expect. The relation between the first checkpoint grading and the final grades is shown in Table 2.

Final Grades	Green	Yellow	Red
10-11			4
12-13		2	
14-15	2	2	
16-17	4		
Not approved			1

Table 2 - Final grades in terms of the first checkpoint grading.

The results were very positive since only one student failed the assignment and clearly it was because of lack of interest (missing several checkpoints). Also, two of the lower grades resulted in bad planning (these two groups were behind after receiving a red card) and had they had an extended deadline they were sure to produce better results since they were on the right track.

The global evaluation resulted in significantly better grades than the previous year (Figure 2). The main reason for this was a well organized planning by setting specific requirements and checkpoints in order to help the groups stay focus without reducing their autonomy. Also, the groups accepted the responsibilities they were given and responded with enthusiasm to the theme.
This was possible because of small number of students in the 2nd year of Biomedical Engineering that allowed a group organization of no more than two elements but also a close coordination between the two courses' teachers.

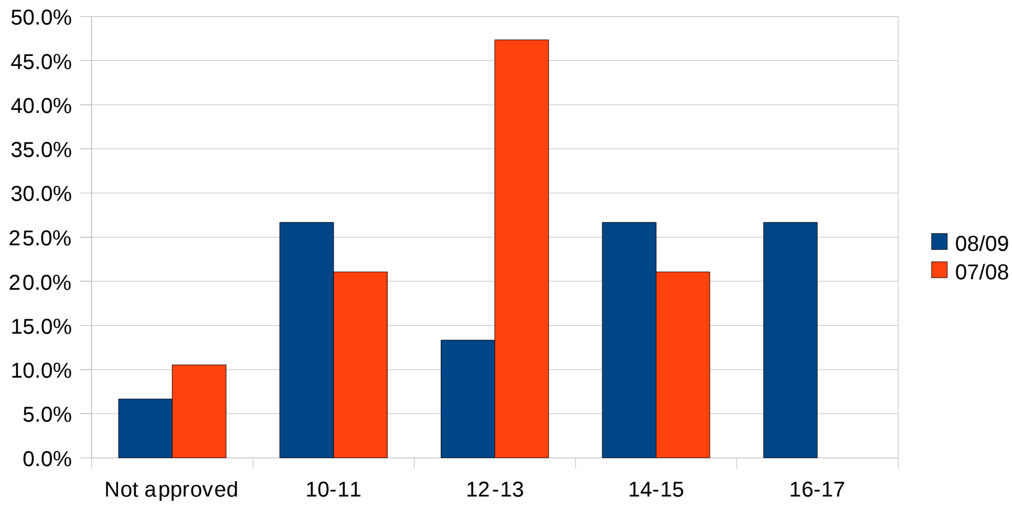

Figure 2 – Comparative final results.

4. CONCLUSIONS

To develop the necessary skills of a Biomedical Engineer is a difficult task to do in a 3 year degree, especially without compromising the extension of the course program. This is the Bologna's paradigm and in this article we proposed a student-based learning methodology that is project-based learning.

Results were very satisfying and although we cannot have any comparison with the pre-bologna evaluation, the evolution of the evaluation method is more than evident.

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PEDAGOGICAL IMPACT OF THE MULTIMEDIA ENHANCED ELECTRONIC TEACHING SYSTEM (MEETS) ON THE DELIVERY OF ENGINEERING COURSES

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Abstract: This paper presents an innovative practice based on the Multimedia Enhanced Electronic Teaching System (MEETS). The practice was developed and successfully implemented for a core undergraduate course in Mechanical Engineering on mechanics. The MEETS was rigorously designed in response to the growing need of effectively teaching courses with large enrolments, while still allowing demonstrations, which traditionally have been limited to smaller classes. The MEETS includes (i) two video projectors, (ii) two document cameras, (iii) a personal computer (PC) for showing animations, and (iv) the Easel Paper Dispenser Display Adapter (EPDDA), which allows the lecturer to write lecture notes on an area of a letter sized sheet of paper. Images from the EPDDA are shown using one of the document cameras. The lecturer controls which images are shown on the video projectors.

Keywords; multimedia presentations, teaching of mechanics, visual aids, large classes, pedagogical impact, recording of lectures.

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1. INTRODUCTION

In the teaching of University level courses on mechanics, it is critical to clearly explain and demonstrate the motions of machines with appropriate diagrams, live demonstrations and animations. The authors developed several methods to effectively display such motions of machines. These include creating animations using a PC, such as Cleghorn (2005), and fabricating physical models for display using a document video camera, such as Cleghorn and Dechev (2003). To accompany the demonstrations, lecture notes were presented using a traditional overhead projector and transparency roll.

In the past decade, PowerPoint has been commonly employed by University and College instructors. However, employing PowerPoint incorrectly may give rise to difficulties. There could be less participation by the students and a tendency to present material at too high of a pace for the students to follow. As Brown (2009) argues, the use of instructional technology is not beneficial to teaching or learning when the purpose is not clear and it is merely used as a "placeholder". In addition, good use of instructional technology engages the students in active learning and supports interactive demonstrations. Two years ago, the first co-author surveyed the undergraduate students in his Mechanical Engineering course. They indicated their strong preference to take handwritten notes from material written by the instructor during lectures either on transparencies or the chalkboard.

The preference of the Engineering students was to be actively engaged in the learning process during lectures rather than view projected still PowerPoint images. This is completely consistent with Bonwell and Eison (1991) that in-class writing is productive and ensures students are thinking about the notes that they are writing during lectures.

More recently, tablet PCs are being used to overcome the challenges of static PowerPoint lectures and have gained a wider acceptance for University and College teaching. The tablet PCs have the following advantages over traditional chalkboards and whiteboards:

(i) There is no need to periodically erase material.
(ii) It is possible to review previously presented material (i.e., go backward).
(iii) Projected images can be much larger and more suitable for large classes.
(iv) Other media, such as video, may be incorporated to support presentations, and there is no need to employ separate equipment.
(v) One can more easily overlay annotations on prepared images.
(vi) The instructor may remain facing the students, allowing more effective presentations without the instructor having to turn away for writing.
(vii) It is not essential for the instructor to remain front and centre in the classroom. Students may concentrate on the material being presented on the projection screen, while the lecturer is off to one side.
(viii) One can archive and replay presentations after lectures, and publish to course management systems.

The above advantages are considerable, and should be incorporated as much as possible in any new procedure.

There are currently record numbers of students enrolled in the Mechanical Engineering program at the authors' university. It is therefore important to have methods which are effective for teaching large classes. For an undergraduate Engineering course on mechanics, it remains extremely beneficial to display the motions of machines. With the ever increasing demands to deliver advanced Engineering course content and ensure students are absorbing the complex material, one obvious option is to develop a means whereby the entire lecture content including the creation of real time mechanical drawings, classroom physical demonstrations (e.g., automotive mechanical components) could be recorded and viewed by students on demand.

This paper presents the Multimedia Enhanced Electronic Teaching System (MEETS), which was intentionally designed for the teaching of large classes, and successfully implemented for a core undergraduate course in Mechanical Engineering. Although the paper presents the results for the teaching of one course on mechanics, the authors believe that the advantages of using MEETS are more universal and can be extended to courses in other disciplines.

2. THE MULTIMEDIA ENHANCED ELECTRONIC TEACHING SYSTEM (MEETS)

2.1 Overview of the MEETS

The MEETS presented in this paper combines and enhances the techniques which were previously employed by the authors. The MEETS uses two high definition document cameras to project hand written notes, illustrate mechanical drawings as they are created, and demonstrate small mechanical systems. Brooks-Young (2007) states that the use of document cameras for teaching helps students in learning new concepts. The MEETS retains the advantages of employing a modern tablet PC, the ease of use of the conventional transparency roll, and is effective for teaching large classes.

Figure 1 illustrates the subsystems and interconnections of the MEETS, which includes two video projectors, and two document cameras. Video projector 1 shows images from either the EPDDA (described in Section 2.2) or from the PC. Video projector 2 is always connected to document camera 2.

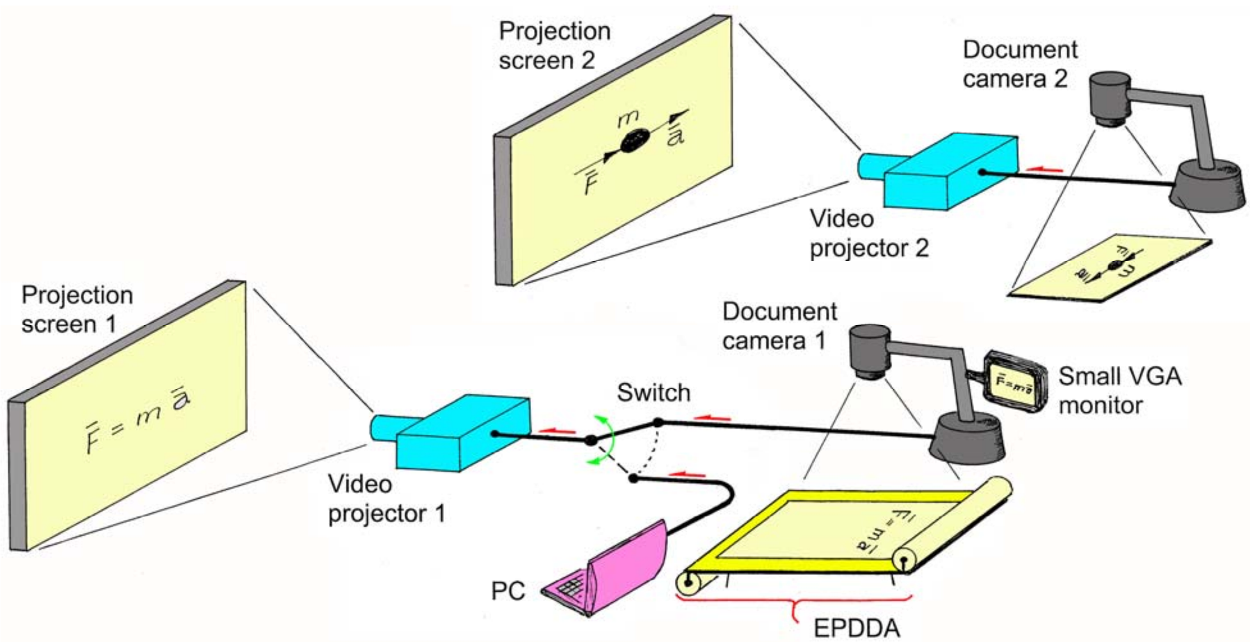
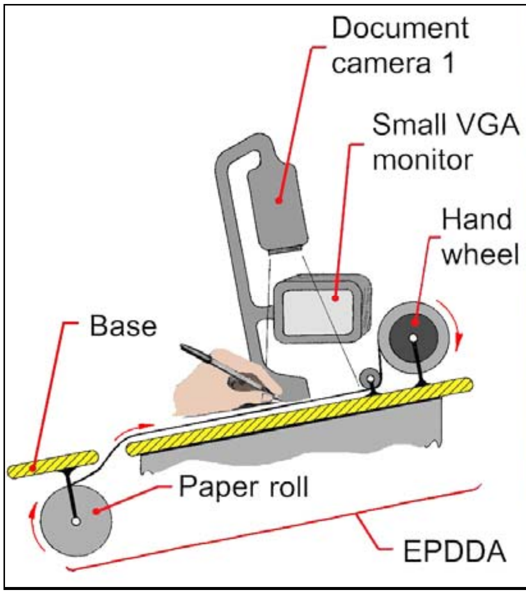


Figure 1 Subsystems and Interconnections of the MEETS.

2.2 The Easel Paper Dispenser Display Adapter (EPDDA)

The EPDDA, along with a document camera and video projector, has some similarities to a traditional transparency roll and an overhead projector. However, instead of a transparency roll, the EPDDA incorporates a paper roll, originally produced for a large-format printer, but modified by trimming to a 30 cm width.

Figure 2 illustrates a schematic of the EPDDA. The modified paper roll is mounted on the feed spool, and its end is fed through a slot in the base of the EPDDA, and onto the take-up spool. Document camera 1 is directed onto the flat portion of the paper on the base of the EPDDA, approximately the size of a letter sheet of paper. The feed and take-up spools are connected to easy to use hand wheels. The instructor may advance the paper by turning the hand wheel connected to the take-up spool, causing the projected images to move slowly upward. The hand wheel on the feed spool may be turned to go back for review purposes. It is also possible to project images from a sheet of letter-sized paper when placed in the viewing area. The sheet may be transferred to document camera 2 so that the EPDDA may be used. The small VGA monitor (17 cm) is intentionally mounted next to document camera 1, and is intended solely for the instructor. The monitor shows the same image as displayed on video projector 1 and acts as a viewfinder for the instructor. Figure 3 shows a photograph of the EPDDA in use.



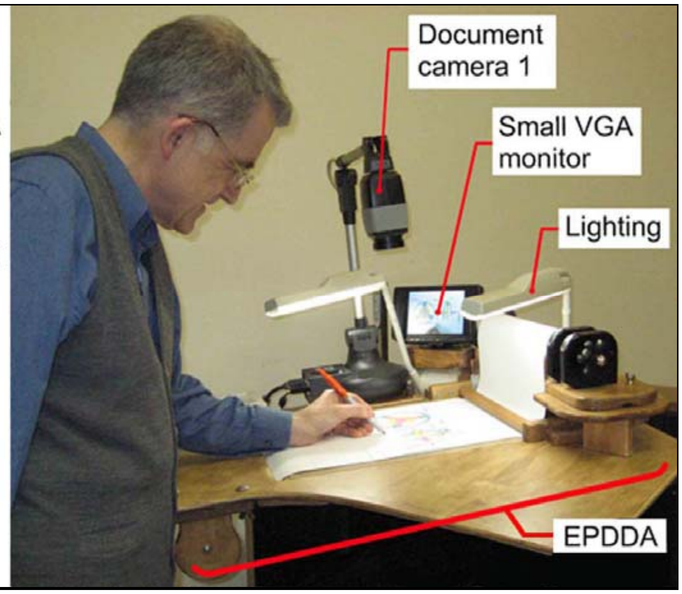


Figure 2 Schematic of the EPDDA. **Figure 3 The EPDDA in Use.**

3. IMPLEMENTATION OF THE MEETS

Prior to lectures, files of illustrations to be covered are posted on the course management system (Blackboard) website. The students are required to print hard copies and bring them to the lectures.

The instructor generally employs the following steps for covering an example:

- (i) Demonstrate either a physical mechanical system using document camera 1 or an animated motion using the PC (display on video projector 1).
- (ii) Show an illustration of the system printed on a page of letter sized paper (display with document camera 1).
- (iii) Annotate the image with the related information, such as the pertinent components and dimensions (display with document camera 1). The students copy the material onto their own copies of the pages.
- (iv) Move the page from (ii) and (iii) to document camera 2 (display with video projector 2).
- (v) Write out the related notes and equations on the EPDDA (display with document camera 1).

Figure 4 shows typical images from the video projectors after the above steps were completed. Projection screen 2 displays the cross section of a manual transmission, while projection screen 1 shows the image of the related governing equations, which were written on the EPDDA.

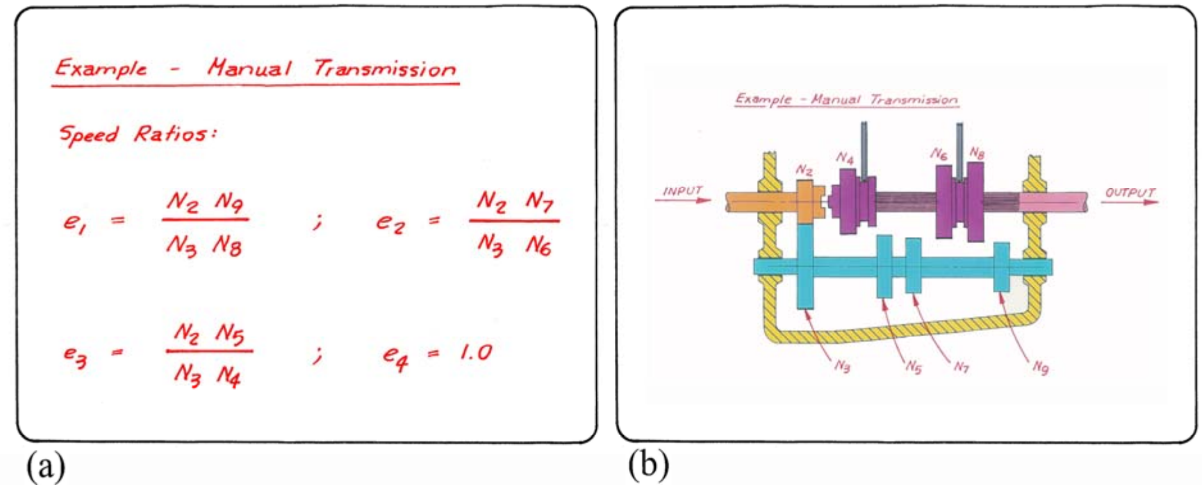


Figure 4 Typical Images from the Video Projectors (a) Image on Projection Screen 1, and (b) Image on Projection Screen 2.

The MEETS has the advantage to provide visual real time physical demonstrations of Engineering systems, and this can provide a positive environment for teaching using other interactive techniques (Bonwell and Eison (1991)). In the demonstration of a small mechanical system using document camera 1, (see item (i) above), it may be required to use the zoom control. In this instance, the instructor should use the small VGA monitor to ensure that the projected image remains in view. Figure 5 shows the demonstration of a small hand held gear train. Figure 5(a) illustrates an instructor demonstrating the gear train using the MEETS. The small VGA monitor shows the same image as that appears on projection screen 1 (see Figure 5(b)). The lecturer need not look over their shoulder to ensure the image is in view.

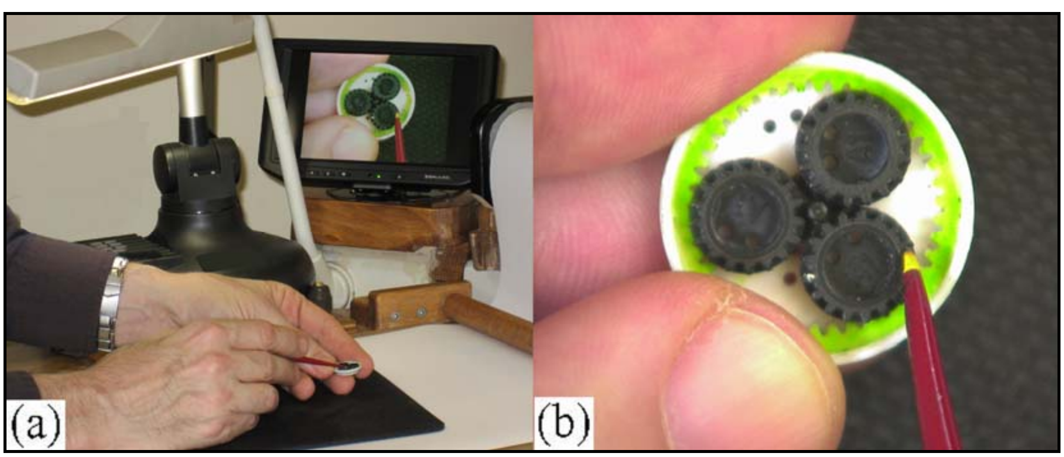


Figure 5 Demonstration of a Small Gear Train (a) Use of the EPDDA/MEETS, and (b) Image on Projection Screen 1.

The EPDDA/MEETS is ideally suited when a significant amount of graphical construction is required on a diagram. The instructor places the diagram in the viewable region. Projected images of the drafting devices and the hand of the instructor are included, which help to clearly show the method used for the construction. Figures 6(a), 6(b) and 6(c) show a sequence of three images for the drawing of a straight line with drafting devices. Figure 7(a) shows the initial image of a four-bar mechanism for which its instantaneous centres of velocity are to be determined, and the final result after drawing the lines is illustrated in Figure 7(b).

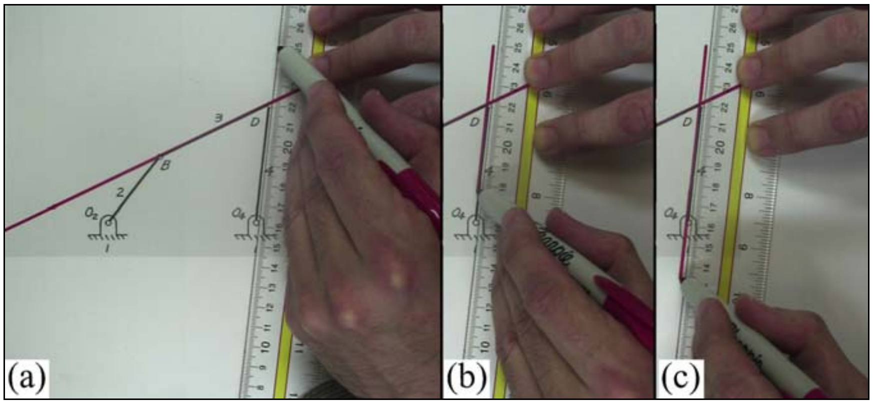


Figure 6 Projected Images for the Drawing of a Straight Line Using the EPDDA/MEETS (a) Before Drawing, (b) During Drawing, and (c) After Drawing.

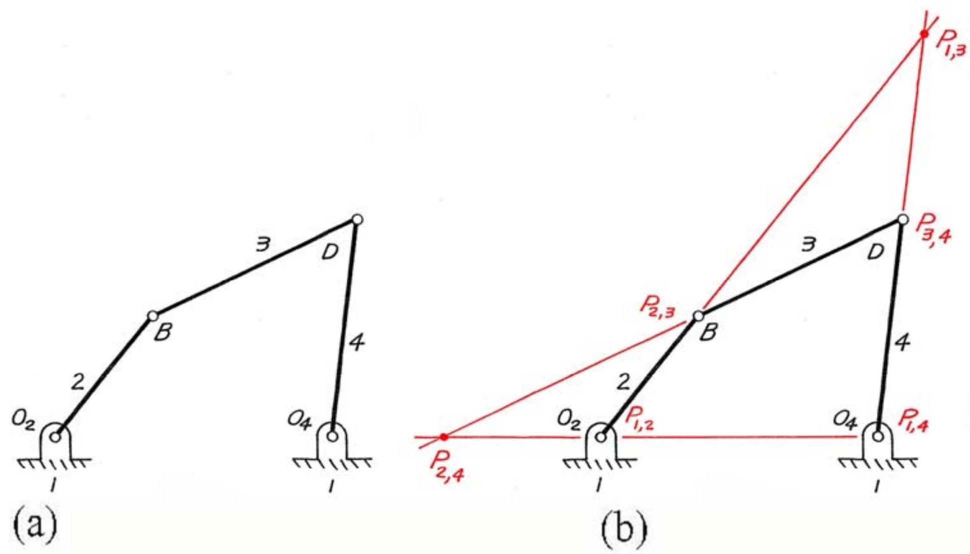


Figure 7 Instantaneous Centres of a Four-Bar Mechanism (a) Before Graphical Construction, and (b) After Graphical Construction.

When the MEETS is employed, the students are active participants rather than passive observers during lectures. They are required to copy the material which the instructor hand writes on the EPDDA. The students leave lectures with annotated and scaled diagrams, which are particularly important for graphical analyses.

4. COMPARISON OF THE MEETS WITH USING A TABLET PC

The MEETS retains the advantages of using a tablet PC over other technologies described in Section 1. The authors feel that the MEETS has the following advantages over using a tablet PC:

(i) The images of the hand of the instructor, along with the drafting devices, appear during writing and graphical constructions. The students therefore naturally follow the material being added, and can readily understand the graphical procedures employed. (see Figure 6) It also allows the instructor to point to the locations of interest. This is superior to having only inscriptions which just appear when using a tablet PC. For instance, Figures 8(a), 8(b) and 8(c) show a sequence of three images of the same graphical construction shown in Figure 6, but now using a tablet PC. Since images of the hand of the instructor are not seen, it would be far more challenging for the students to follow the method used for the graphical construction.

(ii) The MEETS allows the lecturer to demonstrate small physical mechanical components to large classes. (see Figure 5)

(iii) The MEETS allows lecturers to comfortably write lecture notes with the accustomed feel of ink markers and paper. The authors believe that a superior script can be created compared to using a tablet PC.

(iv) The MEETS eliminates any differences of the instantaneous positions of the tip of the marker and the script drawn on the paper. Small differences can occur when using a tablet PC, which may limit the complexity of the text and the diagrams which are drawn.

(v) Images of the written material remain projected a sufficient time to allow students to copy the material. The writing on the paper roll is slowly scrolled up on the EPDDA as the lecturer turns the hand wheel. This is distinct from using a tablet PC for which after finishing with a projected image, the lecturer could immediately advance to the next image, and not leave sufficient time for the students to copy.

5. CONCLUSIONS

The MEETS is used to teach both the undergraduate and graduate courses in Mechanical Engineering, and was employed recently for a large undergraduate course on mechanics with 195 students together in one classroom. The undergraduate students were asked to provide feedback of their experiences of taking lectures with the MEETS. The following comments were submitted: "The MEETS is an incredibly effective teaching tool for large classes."; "... (MEETS) allowed the instructor to show several live demonstrations which helped students attain a practical understanding of the presented material"; "... helped students to clearly follow the lecture material (by showing the actual hand of the instructor writing the material on paper)"; "... allows the instructor to point to important areas of interest on the displayed notes enhanced the quality of communication... "; "... made it easier for students to understand the instructor's writing, especially on annotated diagrams"; "... writing down the lecture notes forces the student to think about what they are writing and thus enriching the understanding of the presented material"; "... helps students actively pay attention in class"; "... having pictorial representations of much of the class material available to print beforehand, and upon which annotations could be made and the bulk of the notes be taken, was a significant aid in the overall neatness of the lecture notes".

Because of the favorable feedback, the authors will continue using the MEETS. The technology used for MEETS is easily adaptable for the recording of lectures. Future plans include recording of the complete lectures with the MEETS projected images using current lecture capture technology and publishing to Engineering course websites.

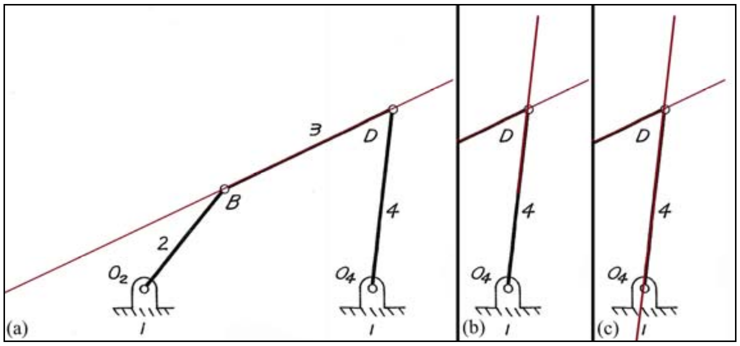


Figure 8 Projected Images for the Drawing of a Straight Line Using a Tablet PC
(a) Before Drawing, (b) During Drawing, and (c) After Drawing.

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ACKNOWLEDGEMENTS

The authors express gratitude to the family of Dr. Clarice Chalmers for providing the financial support for the development of the MEETS. The authors sincerely appreciate Mr. Ernie Lopez, Manager, Classroom Technology Support Group, University of Toronto, for his invaluable and dedicated technical contributions.

FIRST YEAR FLUIDS – ENCOURAGING STUDENT ENGAGEMENT WHEN THE CLASS SIZE IS LARGE

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Abstract: Over the last six years, the authors have been responsible for a first year fluids course given to aerospace, civil and mechanical engineering students. The University had decided that these students should be taught as a single group for core first year courses and the class size has been around 230 each year. This paper aims to show how the teaching methodology was applied to the challenge of a large class and how student engagement was promoted.

There were normally two hours of lectures and one hour of tutorial each week for 12 weeks. The lecture style involved formal teaching interspersed with active learning elements, for example a short question/puzzle for the students to consider. The class was divided into small groups of about 25 – 30 students for tutorials; these ran simultaneously. A 10-minute test was held at the end of each tutorial during weeks 3 – 11. Each test contained five questions based on the previous week's lecture material and the marks contributed towards 20% of the course mark. It was a condition for passing the course that a student must pass at least six of the nine tutorial tests. Thus, the assessment was designed to encourage and maintain student involvement with the course. Each student also had to participate in three laboratory classes – these practical aspects supplemented the lecture material.

It is believed that the teaching was successful and the assessment strategy had the desired effect. Lecture attendance was good and student feedback confirmed the weekly tests were useful.

Keywords: first year, large class, assessment, fluids.

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1. INTRODUCTION

About seven years ago, the University decided that first year aerospace, civil and mechanical engineering students should be taught as a single group for core subjects (maths, fluids, solids and structures) in order to make more efficient use of staff time. Prior to that, the three groups of students were generally taught separately.

The authors were given responsibility for the fluids course and have continued to oversee it throughout the last six years. The class size has been around 230 each year. This paper aims to show how the challenges associated with teaching a large class were overcome and how student engagement was encouraged.

2. COURSE STRUCTURE

There were normally two hours of lectures and one hour of tutorial each week for 12 weeks. A formal teaching style was generally employed in lectures with effort made to present the material clearly and in a logical manner. While the course content (fluid properties; fluid statics – pressure, forces and moments, buoyancy; fluid flow – categories, continuity, Bernoulli and momentum equations) is relevant to all three groups of students, it was important to use a variety of examples and applications to maintain interest across the class.

Attempts were made to intersperse the teaching with active learning elements to promote thinking and learning during the lecture. The students would be given a few minutes to do a short calculation or consider a question or puzzle, for example, finding how deep a diver can be before the pressure on the body has doubled, considering whether walls of different thickness need different levels of formwork support just after the concrete has been poured. Students are often reticent to ask questions or give answers in front of a large class so the questions were often put in multiple choice format and a show of hands requested for each possible answer. Alternatively, the lecturer walked around the room and took a sample of answers from individual students. It is important that lecturers are approachable and it is believed that interactive efforts made in lectures will encourage future engagement.

The class was divided into eight or nine small groups of about 25 – 30 students for tutorials, which occurred simultaneously. Each tutorial class was led by a postgraduate student although the two lecturers aimed to visit all the classes each week, spending about 15 minutes in each. Students were expected to work through questions based on that week's lecture material. Solutions to tutorial questions were made available on Queen's Online (the University's intranet) the day after the class to enable students to complete questions and revise for subsequent tests. Greater student engagement is expected, and did happen, in the tutorials. The group sizes were relatively small and the setting was more informal than the lecture. The postgraduate leader was encouraged to speak to students individually regarding their work and get to know the students by name.

Each student had to participate in three laboratory classes, each of duration 1.5 hours, which supplemented the lecture material on fluid statics, laminar and turbulent flows, and flow rate measurement. The lab classes involved a combination of demonstration and student practice followed by analysis of the data recorded. Timetabling challenges arose due to the large class size. There were typically 44 student groups (5 – 6 students per group on average) and it was aimed to schedule each group's lab classes at a stage during the semester to correspond roughly with the associated lecture material. Recording of student attendance and results (pass/fail) was made more efficient by using Sharepoint. The postgraduate students responsible for the lab classes were expected to enter the data on Sharepoint soon after the classes while keeping a paper copy for backup.

3. ASSESSMENT

A 2-hour exam at the end of the course contributed towards 80% of the overall mark. The first part (40%) of the exam consisted of 20 multiple choice questions – it was necessary to introduce this format to reduce the time involved in marking. For the rest of the exam, students were able to choose three out of five longer, structured questions worth 20% each.

No marks were available for the laboratory element. All work associated with each lab class was expected to be completed within the 1.5-hour session and no submission of work was required. It was desired to keep this aspect of the assessment simple. However, it was a condition for passing the course that a student must attend and participate in all three lab classes. Therefore, only the result (pass/fail/absent) was recorded at the end of each lab class.

The main impetus in promoting student engagement occurred through the system of continuous assessment. A 10-minute test was held at the end of each tutorial in weeks 3 – 11. Each test contained five questions based on the previous week's lecture material and the marks from all nine tests counted towards 20% of the overall mark for the course. It was a condition for passing the course that a student must pass at least six of the nine tutorial tests. Thus, the assessment was designed to encourage and maintain student involvement with the course.

The tutorial tests were also designed for efficient marking. Some questions were of multiple choice format (testing knowledge of definitions, for example) and others involved calculations. Each answer was simply marked right (1 mark) or wrong (zero marks) and no marks were given for method. The pass mark for each test was 2 (out of 5).

It was aimed to give students quick feedback on their tests. The marks were published on Queen's Online within a few days of the test. Students could therefore view the accumulation of marks as the semester progressed and count the number of tests passed. Students had the opportunity of receiving more detailed feedback by speaking to their tutorial class leader (who marked the tests for his/her class) and seeing their marked test.

The condition of passing at least six tests in order to pass the course opens the possibility of a student failing the course by week 6. This could have a negative effect on their engagement. This was countered with the incentive that if the student performed well enough to gain at least 40% overall (through tutorial tests and exam), then they did not have to resit the exam but only sufficient tutorial tests to bring them up to six passes. If a student failed the continuous assessment element at an early stage, and subsequently lost interest in the course, achieving below 40% overall, they were asked to resit the exam, a less appealing scenario.

4. LECTURERS' OBSERVATIONS

The assessment strategy certainly had the desired effect of encouraging student engagement with the course. The condition of passing at least six tests meant that frequent absence from tutorials was not a realistic option. Figure 1 shows the tutorial attendance rate in the weeks when tests were held. The data represent mean values for the classes in 2007, 2008 and 2009.

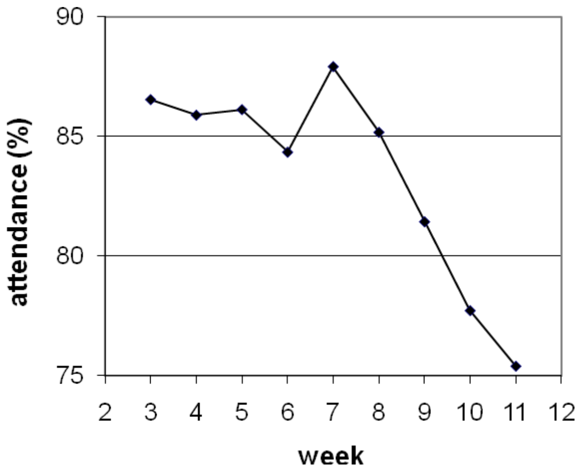

Figure 1: Attendance rate at tutorials during weeks 3 – 11 of the semester.

Attendance didn't reach 100% – some students couldn't attend every week due to extenuating circumstances while a few others (about 6% of the total) were registered but didn't appear for either tests or the final exam. Attendance dropped towards the end of the semester – some probably felt they needn't attend after attaining the required six passes even though the marks from all nine tests counted towards the overall mark for the course.

It is believed that studying and learning, and not just attendance, were promoted. The test questions were such that passing a test would be difficult without having read over the lecture notes and attempted some tutorial questions. Figure 2 shows that only 44% of the class had achieved the necessary six passes at the earliest possible stage. Again, these figures are mean values for the classes in 2007, 2008 and 2009.

Around 17% of the class didn't pass the continuous assessment element. It is noted that this includes some who were registered at the beginning of the course but who probably withdrew during the semester. About 32% of the class passed all nine tests.

The third test was particularly challenging with approximately only 63% of the class passing it. This was not planned but the lecturers subsequently felt that this result, coming at an early stage in the process, would motivate students to work.

The competitive nature of the assessment probably was beneficial and motivational also. Students would compare their results with each other and there was always the personal target of achieving 5/5 or improving on previous weeks' results.

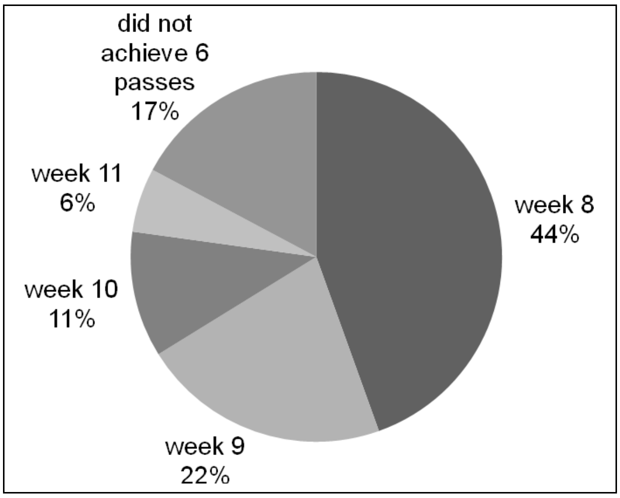

Figure 2: Chart showing proportions of the class and the stage during the semester at which they achieved six passes.

Attendance at lectures was relatively good. There is little data available but records for 2006 indicate an average attendance of about 70% over the semester. (This data includes students registered at the beginning of the course but who probably withdrew before the end.) It is unclear whether the interactive elements of the lectures or the pressure to pass enough tutorial tests had significant effects on lecture attendance.

5. STUDENT COMMENTS

A selection of comments made by students on the end of course questionnaires is presented below. This shows that while continuous assessment was not universally popular, students recognised its relevance to their learning and progress.

> *"Class tests were useful in making you work and learn throughout the year and helped understanding."*
> *"Constant tests were somewhat tiring."*
> *"The idea of tests each week was very beneficial."*
> *"The most useful tutorial structure of any module so far. I feel more prepared for exam through use of the tutorial material than for any other module."*
> *"Weekly tests keep you on top of things."*
> *"Frequent tests good to encourage revision."*
> *"Continuous testing/assessment helped with learning."*
> *"As annoying as the weekly tests are, I feel that I now understand this course better than any other."*
> *"Class tests – good for promoting continuous learning."*
> *"Well set out notes and good interaction."*
> *"Class tests – provided motivation to revise consistently."*
> *"Thought weekly tests were effective and allowed me to see my progress."*

The sample of questionnaire scores (Table 1) also shows some success in encouraging student involvement with the course.

Question	Score (Fluids)	Average score (all first year courses)
Encouraged student participation when appropriate	4.4	3.6
Made me feel that my contribution to class was valued	4.0	3.4
Showed interest in my progress at tutorials etc.	4.3	3.5
Set achievable objectives for coursework/assignments/projects	4.5	4.1
The module was well organised	4.8	4.1

Table 1: Questionnaire scores for mechanical engineering students in 2004. (5 represents "strongly agree", 3 represents "neutral", 1 represents "strongly disagree")

6. CONCLUSIONS

The authors have been responsible for a first year fluids course given to aerospace, civil and mechanical engineering students and have implemented a teaching methodology to cater for class sizes of about 230 students.

While a formal teaching style dominates the lectures, some interactive elements have been included to encourage student participation. For tutorials, the class was divided into smaller groups of about 25 – 30 students. Continuous assessment was performed by a 10-minute test held at the end of each tutorial in weeks 3 – 11. A condition for passing the course was that a student must pass at least six of the nine tutorial tests. This assessment strategy had the desired effect of maintaining student involvement with the course over the semester. The laboratory element was kept simple. All work associated with each lab was expected to be completed within the session and the result was simply recorded as pass/fail/absent.

A very large effort was required in setting up this course. At the start of subsequent years, there was much work in generating spreadsheets to record test and lab marks. Excellent organisation and a well structured plan for the course (tutorial questions and tests following a step behind the lecture material, tutorial solutions going online each week) have been very important. A large team of willing postgraduate helpers for tutorial and lab classes has been vital. Encouraging interaction within lectures has required effort.

Student feedback showed they appreciated the weekly tests, recognising that their learning was being enhanced. It is believed that, despite the large class size, there was some success in promoting student engagement with, and enjoyment of, the course.

DEVELOPING MATHS AND COMPUTING SKILLS IN THE CONTEXT OF AN INTEGRATED CURRICULUM

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Abstract: This paper describes a mathematics and computing module provided for second year aerospace engineering students enrolled on the MEng programme – typically about 20 students. While it has been important to develop students' skills in these areas, the opportunity has also been taken to enhance integration across the curriculum.

The maths section of the course involves more applied topics such as linear algebra, vector calculus and Laplace transforms. Examples relevant to aerodynamics and engineering dynamics are included. Active learning is prominent during the classes. In addition to formal teaching, students work through example questions with the lecturer observing and available to assist.

The computing section is based on Matlab and builds on an introductory Matlab course. It aims to demonstrate application of the maths and show the usefulness of computing tools in aerospace engineering. The content was carefully designed to relate to the maths section and other second year subjects. For example, student exercises include plotting lift distribution on a wing, performing some structural analysis and investigating eigenvalues, before the course climaxes in a mini project on wing design.

Students found the Matlab section to be challenging. However, encouraging feedback indicates that most learn a lot from the course, they observe the applications for the maths and note the relevance to their degree.

Keywords: mathematics, computing, Matlab, aerospace, applications, integration.

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1. INTRODUCTION

The need of business and industry for well educated, motivated and skilled engineering graduates has recently been emphasised. The report also advises that engineering degrees should have an appropriate balance between technical understanding and practical application (The Royal Academy of Engineering, 2010).

The aerospace engineering degree programmes at Queen's University Belfast include the core themes of aerodynamics, aircraft structures, flight mechanics, design and manufacturing. These are supported by topics such as mathematics and computing, systems engineering, electrical engineering, business and professional studies. There is emphasis towards application of engineering principles and there are opportunities throughout the programmes to develop a wide range of skills. Figure 1 shows some of the main themes and associated courses in the four years of the MEng degree. Within each theme, a coherent progression between courses in successive stages is expected – this could be described as "vertical integration".

Stage / year	**Theme**				
	Aerodynamics	**Design**	**Flight Mechanics**	**Structures**	**Mathematics and Computing**
1	Fluids 1	Introduction to Aerospace Engineering 1	Flight Mechanics 1	Solids and Structures 1	Engineering Mathematics 1; Further Mathematics 1
2	Aerodynamics 2; Propulsion 2	Design 2	Flight Mechanics 2	Aircraft Structures 2	Mathematics & Computing 2M; Further Maths 2
3	Aerodynamics 3	Preliminary Design 3; Aircraft Design 3	Aircraft Dynamics 3	Aircraft Structures 3	CFD 3; FEA 3
4	Advanced Aerodynamics 4	Design and Simulation Integration 4		Aircraft Structures and Optimisation 4	

Figure 1: Selection of themes and associated courses in the MEng degree in aerospace engineering.

This paper is focusing on the mathematics and computing theme. In Stage 1 mathematics, it is aimed to provide students with a good grounding in a range of fundamental topics relevant to engineering and to demonstrate some application to real-world situations. It is also desired that students' confidence in their mathematical ability should be enhanced. At Stage 2, in the first semester Mathematics & Computing course, students are introduced to Matlab and learn some basic operations and functions. This is built upon in the second semester Further Maths 2 course where more applied mathematics topics are presented and application of the computing tools to aerospace problems is explored. In developing this course, it was intended to relate to other subjects within the degree programme – "horizontal integration".

The aim of this paper is to describe the Further Maths 2 course and to investigate the learning experiences of the students.

2. COURSE STRUCTURE AND TEACHING METHODOLOGY

The Further Maths 2 course has existed in its current form for three years. It is compulsory for second year aerospace engineering students enrolled on the MEng programme – typically 15 – 20 students each year. The teaching staff (the authors of this paper) are from aerospace engineering.

Class time consists of 24 hours of maths teaching (over the 12-week semester) and 15 hours of Matlab computing (a 1-hour lecture followed by a 2-hour laboratory each week during weeks 1 – 5). The maths is assessed by a 2-hour exam contributing towards 80% of the course mark. The computing is assessed continuously with five short structured assignments worth 2% or 3% each and an open-ended design question worth 8% in the last week.

The maths content involves more applied topics including linear algebra, multiple integrals, vector calculus and Laplace transforms. Examples relevant to aerodynamics, structural analysis and engineering dynamics are presented. The aim is to develop a sound understanding and practice of essential mathematics tools used in engineering.

The 2-hour lecture slot each week contains a combination of formal teaching and student work on example questions. The latter activity is introduced as appropriate, for example at the end of a topic, and students have opportunity to practise what has been taught. This keeps students alert and allows feedback (both for themselves and the lecturer) on their progress. Students consulting with their peers on the questions is not discouraged – their learning can be enhanced through the explanation of another. Having a mixture of activities during the class is also advantageous in that it simply breaks up the 2-hour session, helping to maintain student attention and involvement.

Even during the formal teaching sessions, student participation occurs with students asked for answers as a worked solution is developed. This can be achieved relatively painlessly given the small class size and the fact that the students know each other very well.

The first semester computing course involves the basic workings and functions of Matlab. For almost all students, this is probably their first introduction to Matlab. The computing in Further Maths 2 follows on from this and aims to encourage a systematic approach to problem solving and apply the maths and computing tools to aerospace engineering.

Students' skills are built up in the early weeks as the course covers loops, functions, writing to files, good programming practice, etc. These skills are then applied to aerospace engineering problems, for example estimating the lift on a wing and using this to calculate the torsion in the wing structure. Some time is spent manipulating matrices, solving sets of equations and calculating eigenvalues to help understanding of these topics which also occur in the maths section. This leads to the final project, a more loosely defined problem on shear force and bending moment for a wing. This involves tasks based on what the students have learned so far but they are now expected to interpret and plan the steps themselves. With the deliberate exception of this final project class, there is plenty of interaction between lecturer and students in the lab sessions with students able to receive individual attention.

3. STUDENT LEARNING EXPERIENCE

Student performance in both the maths and computing sections of the course has been good with typical average marks of 65% and 73% respectively. This level of achievement is to be expected of MEng students.

Comments written by students on questionnaires showed that most recognised the relevance of the maths, especially to aerodynamics and propulsion. They indicated that they gained a better understanding of the various maths topics and had learned new methods.

> *"Really helps for aerodynamics and parts of propulsion."*
> *"Clear link between maths being taught and the other modules, especially aerodynamics."*
> *"Greater ability to apply maths to other modules as aside from just within its own module."*

The students seemed to enjoy the style of teaching.

> *"Breaks and tutorial questions help break up session and keep my attention span."*
> *"Good explanations and examples to reinforce information being taught."*
> *"Clear and concise, structured, good support for examples."*
> *"Good, involving, how teaching should be."*

These views are reflected by a relatively high rate of attendance at classes. Data for previous years is unavailable but in the current year, attendance at the maths classes averaged 78% over the semester.

Aspects of the computing were found to be difficult. The application of Matlab to the aerospace design project was particularly challenging. However, students were able to identify personal gains from the course. It is interesting that some students focused on subject-specific skills while others mentioned transferable skills.

> *"Ability to more clearly structure my approach to problems and be more methodical in solving them."*
> *"Troubleshooting skills, breaking down engineering concepts into Matlab code."*
> *"Understanding of practical uses for Matlab."*
> *"Better understanding of how to apply Matlab commands."*
> *"How to analyse and work through more complex problem."*
> *"A better understanding of Matlab. Second part allowed for better and useful programmes to be written."*

It is also noteworthy that some students could deduce why an assignment might not be tightly defined.

> *"Sometimes not defined specifically, however this may be to show various ways of achieving an answer."*
> *"Freedom of finding ways to solve problems."*

A variety of responses was received concerning the relevance of the computing section. Most students noted the aerospace applications and links to other modules in the degree programme – structures, aerodynamics and design were mentioned. A few were not convinced that these links were of much significance. Interestingly, one student stated that the main relevance for him was that it prompted an improvement in his approach to problem solving in general.

> *"Tied into a number of modules both past and present."*
> *"All applications were aerospace orientated."*
> *"It changed my approach to problems. I feel more comfortable in my approach to problems in any subject."*

The authors believe that the current approach represents an advance in the teaching of computing. Previously, the computing coursework was heavily dependent on aerodynamics (the lecturer at that time was an aerodynamics specialist). Students disliked this, complaining that a sound understanding of aerodynamics theory was necessary to attempt the computing project. They felt the assignments were complicated and their coding ability was insufficient. The current methodology, involving a gradual building of computing skills and a wider range of aerospace applications, is thought to be more effective in developing students' skills.

4. CONCLUSIONS

The Further Maths 2 course is provided for second year aerospace engineering MEng students. The maths section of the course contains applied topics including linear algebra, vector calculus and Laplace transforms. The computing section is based on Matlab and aims to apply the maths and computing tools to aerospace engineering problems. In addition to enhancing students' skills in maths and computing, it is desired to connect with other subjects across the degree.

Most students recognised the relevance of the maths, especially to aerodynamics and propulsion. They believed they gained a better understanding of the various topics. They seemed to enjoy the classes which involve both formal teaching and student practice, keeping students involved.

Implementing a solution to the design project in Matlab was found to be challenging. However, students noticed benefits of the course, both in terms of improved programming ability and learning a more methodical approach to problem solving. The aerospace applications and links to other subjects in the degree programme were observed.

It is concluded that the course makes an important contribution to developing students' skills in maths, computing and general problem solving. There is some success in promoting integration between various subjects across the curriculum.

5. REFERENCE

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CASE STUDY ON THE INAUGURAL DESIGN AND CONSTRUCTION OF A REFUGEE SHELTER FOR SECOND YEAR ENGINEERS

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Abstract: This paper describes the development of a new design project for the second year of the Bachelor of Engineering Degree at Trinity College Dublin (TCD). The project comprises an open ended design and build exercise that integrates civil and mechanical engineering. The students are required to design a refugee shelter for an extreme climate with a number of requirements including the following: the shelter must be light weight and portable, it must be able to store food above ground, it must be able to collect and store water and it must facilitate a solar cooker. The students work in teams of typically ten persons and are required to deliver a design report and poster presentation. The report must clearly show design concept, calculations, project management, health and safety and sustainability. Following a public exhibition of the posters, the top ten designs are selected for construction in the grounds of TCD. Teams are assessed on their ability to construct their own design, the robustness of the finished shelter and their project management throughout the day. This paper provides an overview of the design project, how it was facilitated and a description of the top designs. Furthermore, comments regarding the problems with running a new design challenge for the first time and suggestions for improvement are provided.

Keywords; Design and Build, Refugee Shelter, Second Year Engineers, Inaugural

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1. INTRODUCTION

This paper describes the introduction of a new problem-oriented, project-based engineering design course taken during the second year of the four-year Bachelor of Engineering (B.A.I.) degree program at the School of Engineering, Trinity College Dublin (TCD). The School of Engineering comprises the following three main disciplines: Civil, Structural and Environmental Engineering; Mechanical and Manufacturing Engineering; Electronic and Electrical Engineering. The core philosophy of the B.A.I. degree programme is to establish the basic principles common to all aspects of engineering. All B.A.I. students follow a common programme for the first two years of the course, followed by two years of specialisation in the different branches of engineering. This allows the program to produce engineers who are well rounded and adaptable and can apply all branches of engineering to their chosen specialty.

In the first two years of the course, the students consolidate their knowledge of mathematical and physical sciences, while taking specific courses related to the engineering disciplines. The majority of courses are assessed through final year examinations, tutorials and laboratory work. However, project based learning is introduced through engineering design projects and this is assessed through coursework alone. This allows skills such as teamwork, project management and communication to develop.

Due to the new semesterisation of the college year at TCD in 2009/2010, the second year design project had to be modified to incorporate a decrease in lecture hours. Instead of slight modification, it was decided to review the existing course and create a new project comprising an open ended design and build exercise that integrates civil and mechanical engineering only. The ambitious project designs a refugee shelter and solar cooker for an extreme climate. The project was extremely successful with excellent feedback from the students. This paper describes the project in detail, including the facilitation of the course, the criteria given to the students, how the course was assessed and the learning outcomes for the students. Furthermore, examples of the top designs are provided. Finally, as with any inaugural project, a number of problems associated with the facilitation of the design challenge are highlighted.

2. OVERVIEW OF ENGINEERING DESIGN COURSE

The design course runs throughout the first semester (i.e. 12 weeks) consisting of two exercises involving Civil and Mechanical Engineering. These exercises include the design and construction of a refugee shelter and the design of a solar cooker to be incorporated into the finished shelter. The class has one formal lecture hour combined with an additional 3 hour design workshop per week. For the design workshop, the class are divided into three main sections and allocated two trained demonstrators per section in addition to the course lecturers.

The 2009/2010 class was divided in 20 working groups, each comprising nine to ten students of mixed ability. The students were provided with a design brief along with the expected assignments and learning outcomes for the course. The students were provided with a wide range of multi-disciplinary lectures including the following: Project Management; Human Geography and Refugee Shelters; People Centred Design and Health and Safety; Sustainability and Recycling; Structures and Design; Solar Cooker and Heat Transfer. The lecture order was structured to encourage creativity and design thinking in the early weeks of the project. Due to the larger size of the groups for the new design course (previously, design teams comprised of four to five students), project management, a new element to the course, was introduced at an early stage. This ensured that all team members contributed to the task in an effective manner.

3. DESCRIPTION OF REFUGEE SHELTER DESIGN AND DELIVERABLES

3.1 Design Brief

The students were required to design a refugee shelter for an extreme climate with the following design requirements:

- The shelter must be light weight, portable and easy to erect and dismantle.
- The shelter must be designed for a 5 person capacity of their chosen demographic.
- The shelter must be able to store food above ground
- The shelter must have the ability to collect 70L of clean rain water per week, 20L of which must be stored in case of emergency
- The shelter must incorporate a solar cooker for meal preparation
- The shelter must adhere to all these requirements with a maximum cost of €100

The design teams were informed that the top ten shelters would be chosen for construction. This was to due to space requirements in college and to encourage competition between the groups. They were further informed that novelty and practicality of design were key factors in the judging and therefore encouraged to concentrate on this for the first 4-5 weeks of the project.

3.2 Project Management

Due to the large number of students in each group, the students were asked to prepare a project management plan. This was to include the project management associated with the design of the shelter over the entire semester and the one day construction of the shelter. The students were reminded that during the construction phase, the winning groups would have an additional 8 to 9 members as part of their team; therefore the project management on the day should be given serious thought. To help with this new element of project management, the students were asked to consider the following questions before they began their design:

- Who is the project manager?
- What are the tasks?
- Who are the leaders of each task?
- Who are the team members on each task?
- What are the milestones and deliverables at different points in the construction and design process?

Students were told they could be the leader on one task and a team member of another, but each student must take responsibility for at least one area. Depending on the task, he/she may need help from other team members, however there should be no more that 4 team members working on any one part of the project.

3.3 Report and Poster

Following discussion regarding the preliminary design, the students were asked to hand in a group report and poster for assessment. The group report was to include the following:

- Interpretation of the design requirements for the refugees including their human needs and environmental constraints
- Comparison and contrast of possible structural forms and materials for the shelter
- Communication of the design of the shelter through drawings
- A bill of quantities outlining the components of the design
- A health and safety plan
- A sustainability and recycling plan

The poster was to communicate visually the main aspects and components of the design and convey the overall message of the design interpretation. This would be displayed as a public exhibition and reviewed by the demonstrators and lecturers on the course.

4. DESCRIPTION OF SOLAR COOKER DESIGN AND DELIVERABLES

4.1 Design Brief

Based on a solar flux of approximately 1kW/m^2, the students were required to design a solar cooker to boil a litre of water. As the solar cooker is to be designed for third world countries, it had the further stipulation that it could not cost less than €10 and must be made from off-the-shelf components. The students were given information about the different types of solar cookers available. Furthermore, they were provided with the relevant equations and examples on the design of solar cookers. Finally, they were provided with a number of Journal papers to read and review which would give them additional information for their own design.

4.2 Report

The students were asked to submit a 2000word report for the solar cooker design, along with supporting sketches, diagrams and calculations that include the following information: Introduction; Literature review of solar cooker technology; Theory; Calculations and Results; Discussion; Conclusions; References.

5. ASSESSMENT AND LEARNING OUTCOMES

5.1 Assessment

There is no formal end-of-year examination for this subject, but all students must achieve an overall mark of at least 40% to pass. The overall mark is calculated using the following combination of group and individual assignments. The group assignments account for 60% of the overall mark and are divided in the following way:

- Group report on the interpretation of the design requirements for the refugees including their human needs and environmental constraints and the comparison and contrast of possible structural forms and materials for the shelter - 25%
- Poster presentation - 15%
- Project Management Plan - 10%
- Construction and testing of the designs - 10%

The individual assignments account for 40% of the overall mark and are divided in the following way:

- Structural hand calculations for the design of the refugee shelter - 10%
- Health and safety plan and a sustainability and recycling plan - 10%
- Full design of solar cooker - 20%

5.2 Learning Outcomes

On completion of this course, it is anticipated that the students will be able to:

- Interpret a design brief for a refugee shelter that meets the needs of a well-defined specification for a hostile environment
- Be part of a team either as the team leader or a team member and work on a multi-disciplinary project with a fixed deadline
- Define a design problem and carry out the necessary analysis and calculations
- Communicate the design using design statement, engineering drawings, calculations, bills of quantities, and an oral presentation
- Project manage the construction of a shelter and overcome practical problems
- Design and build temporary demountable and adaptable structure, understand health and safety issues associated with construction projects and prepare a health and safety plan
- Understand recycling strategies and elements of sustainable design

6. POSTERS AND SHELTER CONSTRUCTION

6.1 Winning Designs
The top three refugee shelters from the poster design and shelter construction have been chosen to be reviewed as part of this paper in order to demonstrate the outcomes of the course. These are 'The Ark', 'The Cardboard Cradle' and 'Ref Shel'. Each shelter incorporated different innovative aspects of the design brief, including water collection and living space, sustainability and ease of erection.

- 'The Ark' was designed using bamboo poles for the structure connected at a central point with a water proof cover fixed to the shelter. The water proof cover had the facility to collect water and incorporated flaps which could be open to allow adequate ventilation if necessary and closed to provide 5 separate sleeping places.
- 'The Cardboard Cradle' used left over cardboard rolls from carpet manufacturers as the main structural element for the design. This allowed the design to integrate a strong element of sustainability.
- 'Ref Shel' incorporated a system which allows the shelter to be erected and dismantled easily. The structural element of the shelter was constructed so that it folded into one single piece for transport and delivery.

6.2 Posters
Figures, 1, 2 and 3 show the posters which were design for 'The Ark', 'The Cardboard Cradle' and 'Ref Shel', respectively.

6.2 Shelter Construction
The top ten designs were constructed during the last week of the first semester, with the winning groups leading the project management for the construction. The groups were given one day for construction and three weeks to prepare parts for assembly leading up to this day. The teams were assessed as a group on their ability to construct their own design, the robustness of the finished shelter and their project management throughout the day.

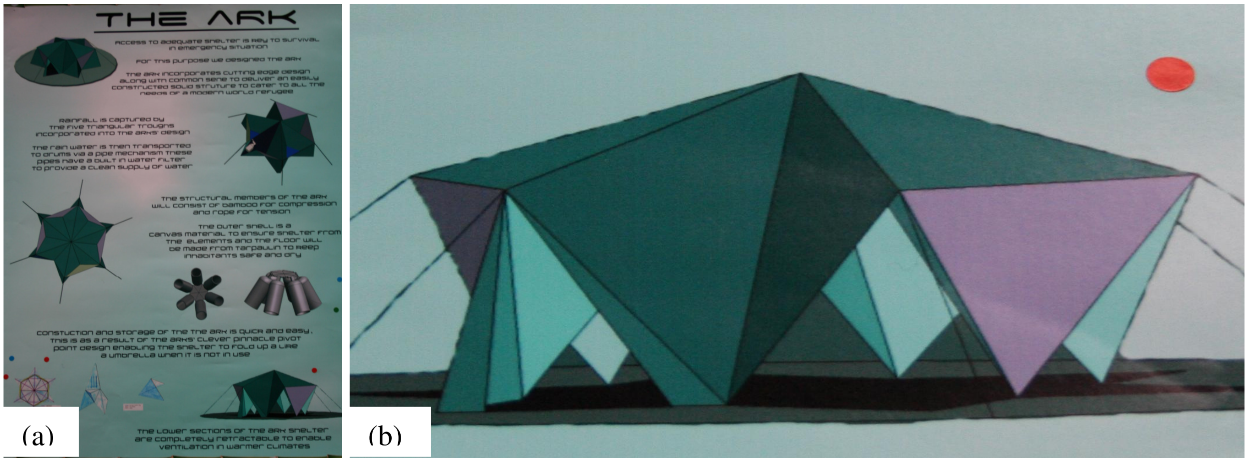

Figure 1 (a) 'The Ark' poster and (b) ventilation flap design

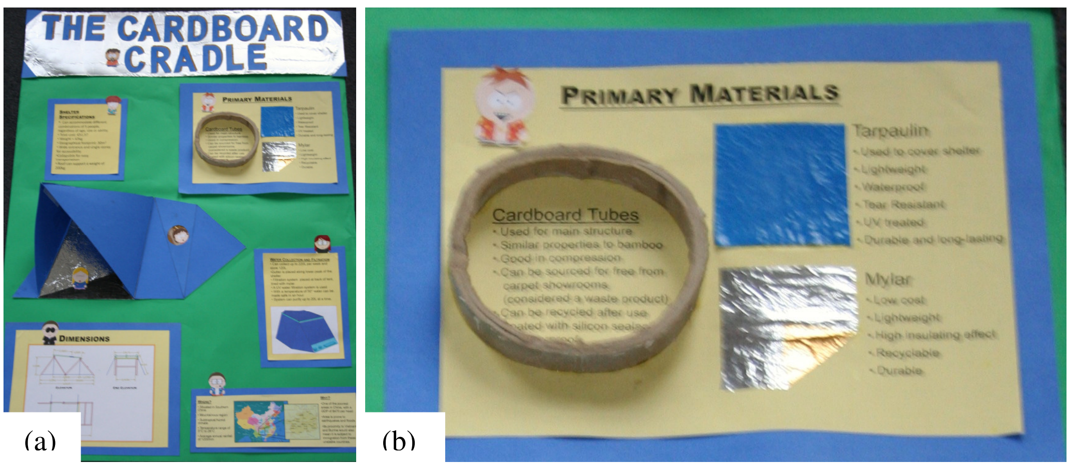

Figure 2 (a) 'The Cardboard Cradle' poster and (b) aspect of sustainability

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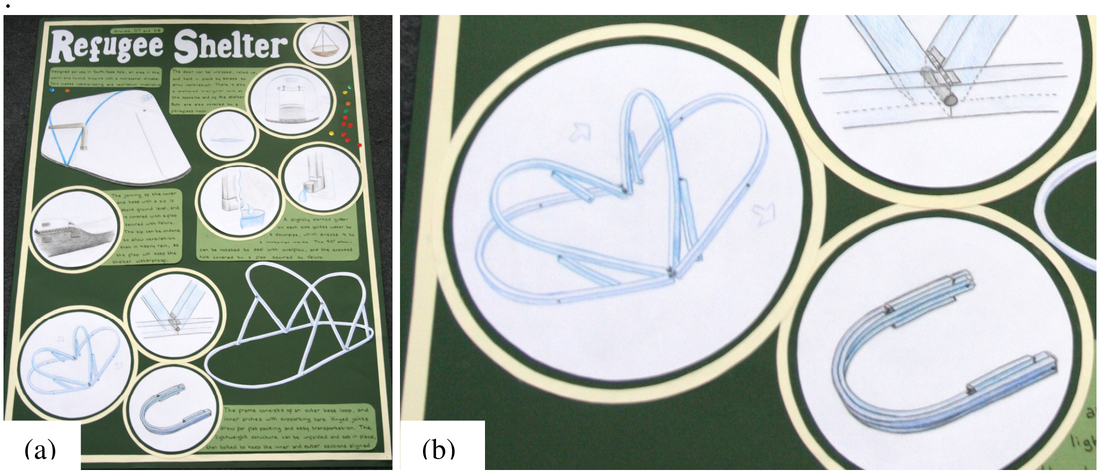

Figure 3 (a) 'Ref Shel' poster and (b) demonstration of transportation and delivery system

Each team was asked to inform the assessors how they constructed their design, what was novel about their idea and any pitfalls they encountered during the day. The constructed 'Ark' is shown in Figure 4 from the inside, highlighting the bamboo poles and central support structure; Figure 5 shows 'The Cardboard Cradle' mid construction, highlighting the use of the cardboard tubes as the main structural element; Figure 6 shows the finished construction of 'Ref Shel' in which timber was used as a more sustainable alternative to the proposed aluminium.

Figure 4 Central Support Structure of the Ark

Figure 5 Mid Construction of 'The Cardboard Cradle'

Figure 6 Finished Construction of the 'Ref Shel'

7. FEEDBACK AND RECOMENDATIONS FOR THE FUTURE

Overall the design project was extremely successful. The students were able to follow a full construction process from design to erection of their shelters; this gave them an excellent awareness of real engineering processes. The students were offered the chance to comment about the course at the end of their report and excellent feedback on the design and application of the course was received. There were many comments relating to the multi-disciplinary approach of the project and how they enjoyed having to think of all aspects of the problem and not just the structural calculations and civil aspects. The design for a chosen demographic and use of space incorporating universal design, was something which all groups took into account and designed well. The ideas for water collection and storage were excellent, with some teams incorporating filtration to ensure clean water even though this was outside of the design brief. The students were very involved in the project; they worked well in their teams and constructed excellent shelters on the day of construction, this resulted in a very high average grade for the course. However, with all inaugural courses, there were a few problems encountered and these are as follows:

- Even though the teams worked well in their groups, the large sizes of the groups were an issue at the beginning of the project. The students found it difficult to understand how to project manage such a large group.
- The students were told not to carry out any calculations until week 4 or 5 of the project; however they felt that without calculations they would not be able to come up with a proper design.
- The portability and ease of erection aspect to the design was largely ignored.
- There was confusion over whether the cost of the shelter was to be calculated for Irish products or the cost of products in their chosen location.
- Some students felt that they did not know enough about graphic design in order to produce a poster of the required quality.

In order to address each of these issues, the course will place more emphasis on project management with an entire workshop dedicated to this and team building in the first week of the semester. The design brief will be given out in 2-3 stages to ensure that each stage is carried out effectively and fully completed before the next task begins. The design brief will incorporate specific dimensions for which the collapsed product must fit into and will clearly state that the cost must be less than €100 for Irish products. Furthermore, emphasis will be placed on using recycled products (such as the cardboard tubes) and unwanted items lying around the home. Finally, there will be an additional lecture given on graphic design in order for the students to understand what is required and to give them tips on how to convey their designs effectively.

8. CONCLUSIONS

The development of a new design project for the second year of the B.A.I. at TCD has been described. The design brief of the refugee shelter and solar cooker have been provided along with how the course is assessed and what the learning outcomes for the students are. Examples of the posters and constructed shelters delivered by the students in the first year are shown visually and it is clear that the course encouraged creativity in design and allowed the students to develop skills such as team work, communication and innovation. As with any inaugural course, a number of problems were encountered such as the large size of the groups and how to encourage the most creative designs effectively, at an early stage. These issues have been discussed and the course will incorporate improvements to address these issues. Overall the design project was an immense success and will only get stronger in the subsequent years.

TOWARDS AN INTEGRATED APPROACH TO ENGINEERING ETHICS

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Abstract: There is an increasing diversity in approaches to teaching engineering ethics due to increasing dissatisfaction with the dominant approach which uses case studies focused on moral dilemmas confronting individual engineers. There has been a demand for a greater consideration of the organisational and social context in which engineers work and for a shift in focus from micro ethics issues concerning individuals to macro issues of concern to the engineering profession. Further, there has been a demand that engineers focus on societal decision making about technology and their role in policy development. Drawing on the work of the American sociologist George Ritzer, which focuses on micro/macro integration and the subjective and objective dimensions of sociological analysis, this paper provides a framework for understanding different approaches to engineering ethics. In moving towards an integrated approach, it is argued that a key issue confronting engineers is how to change the economic and social context in which they work so that it enables rather than constrains the development of sustainable engineering solutions. It is also argued that an integrated approach should focus on integrating the different levels of analysis into accounts of ethical issues.

Keywords: Engineering ethics, macro ethical issues, sociology, sustainable development, agency-structure

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1. INTRODUCTION

A recent review (Colby and Sullivan 2008) of the provision for engineering ethics (EE) teaching to US undergraduates concluded that provision for ethics education is inadequate (p. 334), discussion of cases is the most prevalent means of teaching, and that “the broad public purposes of engineering receive little attention” (p.330). The review suggests that “in developing educational efforts to foster ethical development, it is helpful to think about the goals in broad terms” (p.335).

Colby and Sullivan have joined a growing list of scholars who have argued for the broadening of EE arising from dissatisfaction with what can be called the individualistic approach (Conlon and Zandvoort 2009). Various alternatives have been suggested including a demand to focus on macro issues (Hekert 2001), to use an approach based on social ethics (Devon and Van De Poel 2004) or aspirational ethics (Bowen 2009). Others call for a fuller engagement with Science, Technology and Society (STS)[1] studies (Bucciarelli 2008, Herkert 2006, Lynch and Kline 2000) or the philosophy of technology (Son 2008). Further, Mitcham (2009) has identified a “policy turn” in EE which seeks a focus on action to transform institutional arrangements and policy directives as they affect engineering practice. I have argued for such

[1] STS is the study of the interrelationship between technology and society. STS focuses on a range of issues including the relationships between innovations and society, and of organisational culture and risk.

a focus (Conlon and Zandvoort 2009) and that it is particularly important in light of the demand that engineers practice and promote the principles of sustainable development (SD). This will require the profession to influence change in “social, political, economic, and institutional paradigms…thus increasing…our ability to move in sustainable directions” (Donnelly and Boyle 2006 p.153).

All of this presents quite a challenge to those attempting to integrate EE into engineering programmes. Given a divergence in approaches it is necessary to develop tools to understand these different approaches and how they might relate to each other. This may allow us to explore the possibilities for developing an integrated approach and set out more clearly what is required to address the inadequacies in the dominant approach.

In what follows different approaches are analysed using a framework derived from the sociologist George Ritzer. Sociology is a multi-paradigm discipline and Ritzer (2001) wants to move towards an integrated approach. In doing so he has sought to map out different approaches to social analysis as a first step in moving towards integration. I think this framework can be used to look at different approaches to EE. I proceed as follows. First, Ritzers’s framework is outlined. It is then applied to analyse different approaches to EE. The conclusions focus on the implications of this analysis for an integrated approach and for the EE curriculum.

2. PARADIGMS IN SOCIOLOGY

Drawing on Kuhn’s work on scientific paradigms Ritzer (2001) argues that sociology is a multi-paradigm discipline. This has lead to confusion for those approaching the discipline but also to partial explanations of social phenomena as different paradigms focus on different questions and modes of inquiry. He defines a paradigm as “a fundamental image of the subject matter within a science. It serves to define what should be studied, what questions should be asked, how they should be asked, and what rules should be followed in interpreting the answer obtained” (p.60). Ritzer provides a framework for distinguishing different paradigms as a basis for developing an integrated paradigm (Figure 1).

	Macroscopic		
Objective	**i. Macro-Objective:** Examples include society, law, bureaucracy, technology and language	**ii. Macro-subjective:** Examples include culture, norms and values.	Subjective
	iii. Micro-objective: Examples include patterns of behaviour, action, and interaction	**iv. Micro-subjective:** Examples include the various facets of the social construction of reality	
	Microscopic		

Fig 1: Major levels of social analysis

Source: Ritzer (2001 p.93)

This framework is based on four different levels of analysis which emerge from the interaction of two social continua: the macro/micro and the subjective/objective. The macro/micro refers to the magnitude of social phenomena ranging from whole societies to individual action. The objective/subjective distinction refers to whether a phenomenon has a real material existence (e.g. bureaucracy) or exists only in the realm of ideas and knowledge (e.g norms and values). Based on the interaction of these two continua, Ritzer identifies four levels of social analysis as set out in Figure 1.

What Ritzer is doing here is setting out the elements of an integrated approach to explaining social phenomena. In identifying different levels of analysis he is not implying that the social world is divided into these levels. This is simply one way of thinking about the social world and the ways sociologists have approached it. His argument is that an integrated approach must deal with the four levels of analysis: the structure of society, its culture and values, patterns of behaviour and interaction and the consciousness of individuals. An integrated approach focuses on the four levels and “the dialectical relationship…between them” (p.94).

Given the growing dissatisfaction with the individualistic approach to EE and the demand for a greater focus on macro issues, Ritzer’s framework provides a useful tool for both analysing current approaches and developing a more integrated one. Herkert (2005) argues that a framework for linking micro and macro EE issues is missing and suggests that a focus on the role of professional bodies may be one approach to developing an integrated framework.

Ritzer’s framework is useful given the view that a shift to the macro level leaves no role for individual engineers in ethical decision making (Son 2008). Ritzer’s highlights the importance of both micro and macro levels of analysis and their integration and encourages us to consider not only how the social structure affects what people do but also how what people do affects the social structure (2001 p.96). A more integrated approach may allow us to focus on the relationship between social structure and human action and the manner in which structures both constrain and enable action.

3. PARADIGMS IN ENGINEERING ETHICS

Ritzer’s framework can be used to look at different approaches to EE (Figure 2).

	Macroscopic		
Objective	**i. Macro-Objective:** Focus on social, economic and political structures and public policy	**ii. Macro-subjective:** Focus on goals and values of the profession	Subjective
	iii. Micro-objective: Focus on organisational culture and processes and the ability of engineers to prevent the normalisation of deviance	**iv. Micro-subjective:** Focus on consciousness of individual engineers: their ability to identify and solve ethical dilemmas and their ethical will power	
	Microscopic		

Fig. 2 Levels of analysis in engineering ethics

Different paradigms do exist and my focus here is on capturing the fundamental image of the subject as presented by each paradigm. Using Ritzer’s framework Figure 2 sets out what I see as four distinct approaches. The following sections will briefly discuss (in reverse order) each paradigm. I will conclude with some the implications for developing an integrated paradigm for the EE curriculum.[2]

4. PARADIGM IV: MICRO SUBJECTIVE

I will call this approach the individualistic approach (Conlon and Zandvoort 2009) as the main focus is on the consciousness and commitment of individual engineers and their ability to identify and resolve ethical dilemmas (Shuman et al. 2004). This approach focuses narrowly on the ethical commitments of individuals, uses simplified case studies to “train” students to be sensitive to and resolve ethical dilemmas, and sees whistleblowing as a key device for ensuring that engineers can remain true to their ethical codes. Conlon and Zandvoort (2009) have identified key features of this approach.

There is an almost exclusive focus on individuals who are facing a dilemma and from whom an ethical decision is expected involving a challenge to the interests of the organisation in which the engineer works. A key objective is to improve ethical will power.

Codes of ethics are assumed to be the principal source of rules that guide ethical decisions. If for some reason elaboration of the rules provided by the ethical codes is considered necessary, this approach falls back on traditional moral philosophy for help. This focuses on small-scale human interactions, while ignoring the ethical problems of multi-actor situations that frequently arise within the context of engineering and technology.

There is an assumption that “win-win” or “creative middle way” solutions, where one must choose among two or more conflicting morally important values, always exist and can be implemented by individual engineers.

Key problems with his approach include[3]:

1. The assumption that win-win solutions exist for ethical problems that engineers encounter and that individual engineers can implement their proposed solutions. Implementation of their solutions may not be within the capacity of individual engineers as they may require changes to the context in which they work. The scenarios used do not faithfully reflect how engineers actually practice engineering. In focusing solely on an individual agent’s possible courses of action, these scenarios and exercises not merely oversimplify, but they are uninformative about the social, organisational and political complexities of practice (Bucciarelli 2008). A related point is that the focus on clashes of interest between management and engineers means that engineers own practices are not subject to critical examination. The assumption is that engineers need to be emboldened to resist amoral managers (Lynch and Kline 2000).

2. It diverts attention from the macro-ethical problems of the profession (Herkert 2001, 2005). Herkert argues that engineers should collectively be involved in debates over

[2] There are two methodological issues which might arise here. First there is the issue of how many levels of analysis there should be and secondly the extent to which each approach can be seen to be an integrated paradigm. In this short paper its not possible to give extended coverage to these issues other than to say that the framework offered allows me to capture what I see as essential differences between approaches to EE. It is the case that within some quadrants there are more coherent approaches on offer.

[3] Rather than provide a long list of references here I refer readers to Conlon and Zandvoort (2009) which contains an extensive bibliography.

public policy regarding the development and use of technology. Paradigm IV though is about providing students with an understanding of the nature of engineering ethics: “the value of engineering rather than the values of an ethical engineer” (Shuman et al. 2004). A shift to a focus on macro issues requires that engineers reflect on the goals of engineering which should be realised through engineering practice and public policy.

5. PARADIGM III: MICRO OBJECTIVE

In light of these deficiencies some have called for alternative approaches to EE. In other to address the failure of Paradigm IV to adequately address the context of engineering practice some have argued that EE should be informed by Science, Technology and Society (STS) studies (Lynch and Kline 2000, Kline 2001, Bucciarelli 2008).

Paradigm III tend to focus on the question as to why accidents happen. The focus is on organisational culture and processes with exemplary work being Vaughan’s (1996, 2008) analysis of the Challenger disaster. Her analysis emphasises institutional logics and the manner in which patterns of behaviour develop and become institutionalised within organisations. In the case of the Challenger Vaughan shows how risk came to be redefined leading to a number of launches with a flawed design. This led to what she calls the “normalisation of deviance” within the network of organisations supporting the Shuttle programmes.

Lynch and Kline (2000) draw on Vaughan’s analysis to argue for a focus on the detail of engineering practice in EE and the role of organisational culture and processes. There is a recognition that most engineers operate in an environment where their capacity to make decisions is constrained by the corporate or organisational culture (p.210) The aim is “to explore how engineers can learn to identify features of their everyday practice that potentially contributes to ethically problematic outcomes before clear-cut ethical dilemmas emerge” (p.196). An onus is placed on engineers to exercise imagination to develop strategies to prevent these problematic features from developing in their own practice (p. 202).

Lynch and Kline are keen to avoid what they see as simplified explanations of accidents as resulting from amoral managers responding to production pressures on their organisation. They also want to move away from the idea that ethics dilemmas only arise from clashes between engineers and these amoral managers. While this approach can be welcomed in moving away from simplified case descriptions lacking their organisational and social context it is not without problems.

Firstly, although Vaughan pays considerable attention to the wider economic and political environment in which NASA operated and the way it facilitated the normalisation of deviance and “displaced safety and deference to the expertise of working engineers” (2008 p.74, 1996 p.389) Lynch and Kline’s focus is mainly on the organisational culture. It is important to look at the interrelationship between internal organisational processes and factors in the wider environment such as the level of competition. This is not to argue that production pressures have a direct effect on the actions of managers but that they must be factored into the analysis: “the tension between safety and profit is a matter of degree, and the relationship will be different in different organisations” (Edward and Wajcman 2005 p.169). Therefore what happens at the workplace cannot be seen to be independent of wider forces in society.

Secondly in focusing on the issue of organisational culture they neglect the issue of power. The Challenger case involves an "extraordinary display of power" that overcame the engineers who opposed the launch (Perrow 1999 p.380). Thus the capacity of organisation members to challenge dominant cultural scripts assumes significance (Edwards and Wajcman 2005). Lynch and Kline (2000) fail to adequately specify how engineers who become aware of the normalisation of deviance are to change organisational practice. They (p.199-200) dismiss those who consider the role that engineering professional bodies, codes of ethics, trade unions, lawyers and regulatory agencies can play in bolstering responses to moral problems. Legal requirements may help engineers to resist managerial pressure (Coeckelbergh 2006) and safety levels may be high where safety is taken up as a trade union issue. It is important to examine the range of organisational and cultural resources available to engineers and these may be generated outside the organisation.

In considering Lynch and Kline's approach Swierstra and Jelsma (2006), argue that in "modern technology projects" the necessary conditions for individual moral agency are lacking and that the picture painted by Lynch and Kline is far too rosy. They call for "an institutional ethics" (2006 p.312) and a focus on the relationship between individual moral agency on the one hand and on the individual's enabling and constraining environment on the other. It is both necessary and possible to influence the institutional environment of engineers so as to enable and stimulate them to behave responsibly (see also Winner 1990).

6. PARADIGM II: MACRO SUBJECTIVE

In light of these criticisms of Paradigms IV and III there is a requirement to widen our focus and examine the role of macro issues in EE. Herkert (2001, 2005, 2006) calls for engagement with STS to broaden EE to include discussion of public policy issues of relevance to engineers (2006 p.415). Son (2008) has argued that the shift of focus to the macro level requires, in the first instance, a focus on the goals of engineering. What values should engineers cherish and what is their idea of the good society? This is the basis of paradigm II.

As a key issue for this paradigm is consideration of the goals of engineering, proponents have called for an engagement with the philosophy of technology. Son (2008) has argued that a shift to a macro focus should lead to a questioning of the goals of engineering or current forms of technological development (p. 413, see also Winner 1990). This would seem particularly important in light of the increasing commitment of the profession to SD. This requires that engineers commit to meeting vital human needs, promoting both intra and intergenerational equity and public participation in decision making about technology (Mulder 2008). It also means that engineers reflect on their understanding of social equity and public participation.

In a recent publication, Bowen (2009) calls for an "aspirational ethics". He makes a clear distinction between ethics, the "aims of a life that can be regarded as good" and morality, "the norms that provide specific articulation of these aims" (p.6). He argues that EE has focused on morality. As a result, engineers have to a significant extent forgotten that their primary objective is the promotion of human well being (p.3). What is needed is the development of a genuinely aspirational ethical ethos which prioritises human flourishing through contributing to human well being.

Drawing on Mac Intyre's *After Virtue,* he argues that engineers have "mistaken the external goods of the practice (mainly wealth and engineered artefacts) for the real end of the practice (which is human well being)"(p.12). This has led to an imbalanced prioritisation in engineering of technical ingenuity over helping people. He contrasts the failure to provide the world's population with safe drinking water with spending on weapons and the development of military technology. Bowens is a version of virtue ethics which correctly argues that the goals of engineering are critical in determining which virtues engineers should possess. Virtues assume significance in the context of an aspirational ethos which promotes human flourishing (pp.75, 78). He highlights the importance of engineering institutions supporting virtues in practice.

Bowen identifies the key problem in engineering as the focus on technical ingenuity rather than human flourishing and seems to suggest two reasons for this. Firstly, drawing on the work of the philosopher Levinas, there is the structural problem in that engineers lack proximity with the users of technology. As technological systems have become more complex and global it's more difficult for engineers to interface with users. Therefore organisations should be restructured to bring engineers closer to their customers (p.97).

Secondly, he argues that engineers have not engaged sufficiently in ethical analysis of their activities (p.3), that engineers need to adopt a positive way of life (p.74) and take responsibility for the outcomes of their activities (p. 26). An aspirational approach will stimulate a change in attitudes so as to promote the personal ethical responsibility of every engineer (p.92). A person who "genuinely possesses a virtue would be expected to manifest it through the range of his or her activities" (p.79).

Bowen's approach is useful in reminding engineers of the importance of prioritising people's needs. As Smart(2001) has said, about the work of Levinas, the demand to focus on our responsibilities to others assumes critical importance in a context where "an increasingly global neocapitalism with a culture of individualism has promoted self-fulfilment as the primary preoccupation and produced moral indifference as a consequence" (p.518). It is also the case that such a culture has promoted the commodification of everything including vital resources such as water (Petrella 2001).

The main emphasis for Bowen is on the culture of engineering and the development of an aspirational ethos amongst engineers but there is no discussion of power and no engagement with what has been called the captivity of engineering: "most engineers work within a management structure dominated by the requirement to provide profitable operation of the consumer culture. What engineering is done…is therefore determined by the wishes of the patron expressed through managerial agenda" (Holt 2001 p.498). This has generated a key contradiction for engineers as they struggle "to attain professional autonomy and define standards of ethics and social responsibility within a context of professional practice that demanded subservience to corporate authority" (Noble 1977: 35). A focus on the context in which engineers work and how action at the level of society can enhance their capacity to promote social responsibility is the focus of Paradigm I.

7. PARADIGM I: MACRO OBJECTIVE

At the heart of this paradigm is the demand of Zandvoort et al. (2000) that engineers must accept that they must play an active role in helping to reshape the broader context from which ethical problems arise "whenever that may be necessary" (p.297). This is necessary to help engineers to meet their ethical responsibilities particularly in relation to safety but also to facilitate the attainment of the goals of engineering particularly in the area of environmental protection and SD. In both cases regulation is seen to enhance the capacity of engineers to promote social responsibility and enhance human welfare. This is not to argue that change in regulatory frameworks resolves all issues but rather that "structural change makes certain actions seem necessary while others seem impossible" (Dietz and Burns 1992 p.192, see also Coeckelbergh 2006).

A focus on safety can be seen in De George's (1981) analysis of the Pinto case. His focus is on changing organisations and the laws that regulate them. This he argues would change the approach to safety in many organisations. Taking a wider focus Zandvoort (2005) has proposed wide ranging changes to legal systems to enable socially responsible behaviour in engineering and the promotion of sustainability. But other changes are also necessary. In order to move towards sustainability far reaching social, cultural, economic, political, legislative, regulatory, and institutional changes are required (Donnelly and Boyle 2006, see also Beder 1996, 1998).[4] This means that engineers must engage with public policy and the barriers to change.

Some have argued that there are contradictions between the goals of sustainability and current political priorities. Government policies centred on privatisation, deregulation and the promoting of competition are undermining progress in meeting vital needs such as the provision of clean water (Petrella 2001). Further the promotion of overconsumption undermines efforts to promote more sustainable patterns of consumption and production. Woodhouse (2001) calls on engineers to struggle against overconsumption. Others have argued for long term "thinking to take the place of the present consumer driven fast profit generating…system" (Weiler 2001 p.511). Short term thinking associated with the business and political cycles can undermine the effective application of the Precautionary Principle (EEA 2001) a tool for engineers in avoiding and managing risk and environmental damage

All of this generates a requirement to focus on the organisation of production and consumption and how public policy and patterns of regulation can lead to more sustainable outcomes (Donnelly and Boyle 2006 p.151, Beder 1996) Beder (1998 pp.175-6) shows how laws imposing "previously non-existent constraints" can become "inducement mechanisms" for technological innovations which protect the environment.

But problems remain particularly in moving from one technological system to another. STS scholar Thomas Hughes (1989) has used the concept of "technological momentum" to understand the manner in which technological systems get "locked in" making it hard to change them. In Hughes view systems incorporates both technical and social elements including technological artefacts, organisations, actors, regulatory agencies, laws, education and natural resources. As a technological system grows it develops a mass which is made up of institutions and people who have a vested interest in maintaining it. Mature systems have a quality similar to inertia. The development of the system is on conservative lines and radical change is resisted because it threatens the interest of system actors: "Concepts related to momentum include vested interests, fixed assets and sunk costs" (Hughes 1989 p.77). That is

[4]The Declaration of Barcelona, adopted in 2004 at the First Engineering Education for Sustainable Development Conference, called on educators to prepare engineers to "Participate actively in the discussion and definition of economic, social and technological policies, to help redirect society towards more sustainable development" The full Declaration is available at http://eesd08.tugraz.at/?show=declaration

not to say that change is impossible but that a variety of system components, not just the technical components, must be subject to the forces of change.

Scrase and Mac Kerron (2009) have used the concept of “lock in” to analyse why renewable energy has not been more widely adopted. They make the point that the high capital intensity, longevity and fuel specificity of most capital assets are barriers to change which are compounded by the policies of governments committed to free market ideology and associated investment structures. They point to International Energy Agency estimates that $11 trillion in investment is needed between 2005 and 2030 in the worldwide electricity system and argue that “if we are to move with urgency on to a low carbon pathway, government needs to take a more interventionist stance and not automatically endorse competition”(p. 100).

This suggests that engineers need to be able to evaluate public policy and make proposals for change. They also need to understand the process of technical and policy change including the social, political and economic factors that constrain or facilitate the movement towards sustainable social practices and the use of sustainable technologies.

8. CONCLUSION

This brief review of different approaches to EE suggest there are a wide range of factors to be taken into account in considering the capacity of individual engineers to practice engineering in a manner that is socially responsible and promotes the goal of sustainability. It can be suggested that an integrated approach would incorporate the four levels of analysis into the consideration of any ethical problem and examine both the values and commitments of engineers but also their capacity to act on these values and commitments. The real issue is not, as Herkert has posed it, how to integrate macro issues into the teaching of engineers but rather to develop an approach which integrates the different levels of analysis and takes adequate account of the commitment and power of engineers to pursue such goals as safety, sustainability and the enhancement of human welfare. The focus then is on “which *ends, principles, and conditions* deserve not only our attention but also our commitment” (Winner 1993 p.374 emphasis added).

Rather than trying to neatly demarcate what is or is not a macro or micro issue it might be better to use the sociological distinction between structure and agency (Conlon 2008) as a basis for integrating macro issues into the analysis of engineering practice: “macro/micro debates have largely become debates about the relationship of agency and structure” (Barnes 2001 p.344). It is not always clear that macro and micro issues can be easily distinguished. Herkert (2005) has, for example, identified the design of safe products as a micro issue. But the safety of engineering products and processes is affected by the attitudes and practices of engineers, the organisational culture, the regulatory regime and public policy, which includes policy on product liability which Herkert identifies as a macro issue. A focus on macro issues does not mean that micro issues disappear but rather highlights the need to widen the analysis to look at how the broader environment enables or constrains the capacity of engineers, for example, to design safe products. Such an approach accords with the need identified by those focused on EE and the design process to consider the relationship between individual actions of designers and their institutional and social environment (van de Poel and Verbeek 2006 p.224). This would also require us to look at how individual engineers and their professional bodies seek changes in their environment. This requires a focus on societal decision-making about technology and the role of professional bodies within that process.

Such an approach will be based on multidisciplinary inputs from a diverse range of disciplines. The above analysis suggest that rather than just heading to the philosophy department engineering educators will need to consider the role of the sociology, politics, history and law departments in their efforts to educate socially responsible engineers. This may raise questions as to whether the requirements for teaching ethics can be contained within single and discrete modules or whether engineering programmes should be more fully redesigned to adequately address the challenge of educating socially responsible engineers.

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EDUCATING ENGINEERS AS IF THEY WERE HUMAN: PBL IN CIVIL ENGINEERING AT THE UNIVERSITY OF LIMERICK.

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Abstract: The authors' experiences designing and implementing a new problem based learning (PBL) programme in Civil Engineering at the University of Limerick is described. Focus groups, student and staff learning logs, teaching evaluations, a variety of assessment formats, tutorial dialogue, in-class quiz techniques and informal conversations are used to build a picture of the staff and student experience so far. The authors reflect on their educational priorities, their extensive experience in university education and in professional training and mentoring.

Approaches to specific PBL challenges including timetabling, problem design, PBL process facilitation, integration of learning across subject boundaries and assessment are described.

Keywords: problem based learning, PBL, civil engineering education, innovative teaching, assessment, pedagogy.

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1. INTRODUCTION

The Civil Engineering programme at the University of Limerick (CIVIL @ UL) is unique in Ireland in that it is delivered with Problem Based Learning (PBL) at its core. As the programme nears the end of its second year this paper presents the background, highlights from the story so far and reflections of the staff involved in designing and implementing this new programme.

2. PROGRAMME INTENT

The goal of CIVIL @ UL is, through engineering education, to develop people with a life-long research orientation who can address complex problems in the built and managed environment, developing solutions rationally but creatively by collaborating within teams.

This goal requires the development of appropriate attitudes and habits of mind such that the learner takes responsibility for their own education and develops a lifelong mental habit of reflection (Cowan, 1998). Sir Charles Inglis, former Head of Engineering at Cambridge University encapsulates this succinctly when he states *'the soul and spirit of education is that habit of mind which remains when a student has completely forgotten everything he has ever been taught'* (Inglis, 1941 cited in May, 2009).

Therefore CIVIL @ UL is concerned with:

- personal responsibility for learning
- a research orientation
- reflective practice
- group working and
- communication and presentation skills

We have chosen PBL as the most effective means to achieve these ends. These concerns are process led rather than content driven. Attitudes and habits are not formed by transmitting content, but by embedding work with appropriate content within an effective process. This process is designed to effect behaviour change. That is our mission at CIVIL @ UL.

3. TEACHING AND LEARNING RESEARCH

3.1 Effective teaching practice

As we move our students towards a research orientation we must ourselves inform our practice by research. In designing an effective process we are mindful, from educational research, of a number of conclusions on effective teaching strategies. See, for example, Felder and Brent (2003). The most important for our purposes are summarised as follows:

- Activity (as distinct from passive listening)
- A variety of modes of engagement (visual/verbal, active/reflective etc)
- A task or challenge (i.e. a reason or motivation to seek knowledge)
- A connection with personal experience (a concrete application)
- Use of historical precedent as a context (see Phillips, 2010)
- An opportunity for individual self expression
- Social contact (group activities)
- A teacher who inspires respect.

What promotes respect for the teacher?

- Authority or mastery of the subject matter
- Enthusiasm: demonstrate your conviction that the subject matter is important
- Care: demonstrate concern for and empathy with the students.

3.2 A culture of care

One manifestation of care is to listen to the students' experience of the programme. Research has in this area has unequivocally established that 'student evaluations have high levels of reliability and validity' (Felder and Brent, 2008). As we developed CIVIL @ UL, anonymous feedback has been gathered by the UL Centre for Teaching and Learning using focus groups and on line student evaluation of lecturers and facilitators.

4. WHAT IS PROBLEM BASED LEARNING?

4.1 Common features

Definitions vary but some common features occur. PBL organises curricular content around a problem that stimulates the student to research and learning, generally in a group setting. Lectures deliver content relevant to the problem at the appropriate stage in the PBL process. The alternative term 'trigger' instead of 'problem' points to a distinguishing feature of PBL:

the aim is not necessarily completion of a project but the use of a problem as a 'trigger for learning'. The term 'problem' is adopted here.

4.2 PBL in medicine and engineering

The development of PBL is most advanced in the field of medical education, in particular at McMaster University in Canada (Barrows and Tamblyn, 1980) and Australia, but also in the UK and Europe. Most recently the Graduate Medical School (GMS) at UL has been championing PBL for the past four years.

Among the drivers for the adoption of PBL in medicine was the poor knowledge retention rate reported from conventional programmes, the explosive growth in medical knowledge requiring a lifelong research orientation for medical professionals and the increasingly collaborative nature of medical practice (Barrows and Tamblyn, 1980).

It is interesting to compare current concerns cited in May (2009) on the attributes of many of today's engineering graduates:

'They lack basic skills: thinking it out for themselves, designing, writing, drawing, sketching, presenting, calculating, validating. They have assimilated a lot of knowledge but do not know how to use it effectively.'

This quotation resonates powerfully with the authors' own experience gained mentoring some dozens of graduate engineers in practice over 40 years.

The PBL approach is now established in a number of civil engineering programmes worldwide, notably at Aalborg in Denmark (Hansen and Soerensen, 2003), New South Wales, University of Castilla – La Mancha, Spain and Monash University, Australia.

4.3 PBL and CIVIL @ UL

The proximity of the GMS has afforded the staff of CIVIL @ UL the opportunity to observe a well established PBL process in operation first hand. We have used the GMS process as a model for our own practice and have adopted the following process steps in our approach:

<u>At the first PBL session</u>:

- Appoint scribe
- Brief/problem presentation
- Clarify unknown terms and request essential missing information
- Brainstorm existing group knowledge and solutions
- Organise knowledge
- Propose a tentative solution
- Identify knowledge gaps
- Make research plan
- Scribe reads research plan for transcription by group
- Adjourn.

<u>Between sessions</u>

- Conduct self-study and research, meeting informally as necessary.

<u>Second and subsequent sessions:</u>

- Reconvene
- Read research plan
- Table research
- Organise new knowledge
- Revise or develop solution in light of new knowledge to eventual completion

Our PBL sessions consist of 2 tutors or facilitators and between three and six student groups, with about six students per group (Figure 1). The process promotes knowledge transfer across subject boundaries as all exiting group knowledge is pooled during brainstorming.

Figure 1 PBL Group activity

Figure 2 Trial pitting for geotechnical PBL

4.4 PBL in CIVIL @ UL Semester 4

We now describe the implementation within the Spring semester of Year 2. The structure of the Semester 4 programme is shown in Figure 3.

Thus there are three PBL problems running in Structural Steel and Timber Design (Siege Platform at King John's Castle), Hydrology and Water Engineering (A self-sufficient water supply for UL) and Geology and Soil Mechanics (Geotechnical flood protection structures at UL).

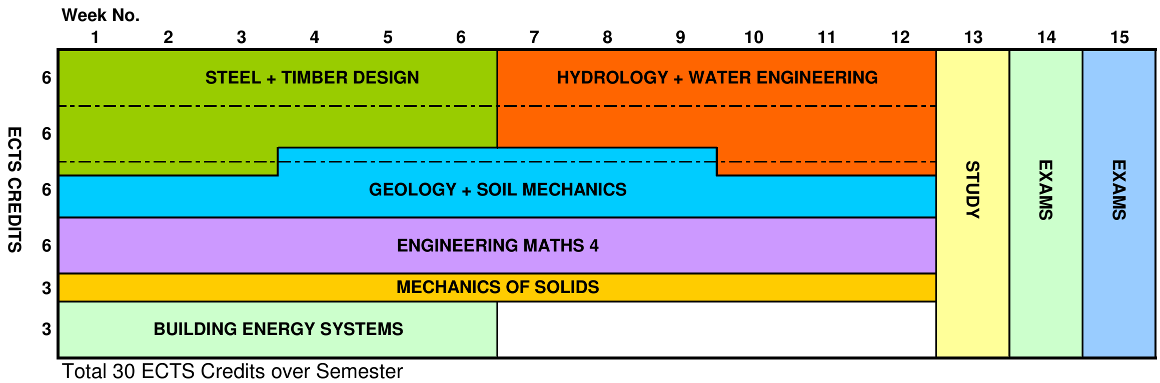

Figure 3 Semester 4 Timetable

5. THE SIEGE PROBLEM

This section describes one of the PBL examples.

5.1 Siege problem design

For Steel and Timber Design the problem was the design *and construction* of 6m high siege platforms at King John's Castle in Limerick. See www.ul.ie/civileng for a video account of the actual siege and Cosgrove (2010) for further background.

Good problem design requires time. Two facilitators critiqued the problem design by solving it including detailed consideration of the construction phase. This reduced problems on implementation. The brief was supplemented as necessary during the PBL sessions.

5.2 Allow for individual creativity

Feedback from students is emphatic that engagement is significantly enhanced when students can express their own creativity during the PBL process. We have therefore moved away from multiple short closed problems to open problems (such as the siege platform) that allow for personal creativity in the solution.

5.3 A single problem per module

A short problem may sometimes be used in first year to give both students and staff the opportunity to practise the PBL process. A single well designed problem, such as the siege problem, can achieve all the required learning outcomes. A supplementary tower problem (design only) extended the timber learning into the steel domain and exposed the students to the nuanced differences in approach required for the two materials. A rich diversity of solutions emerged. Figures 4-6 illustrate some stages in the solution process.

After construction and prior to assessment a session is devoted to reflecting on memorable learning that occurred.

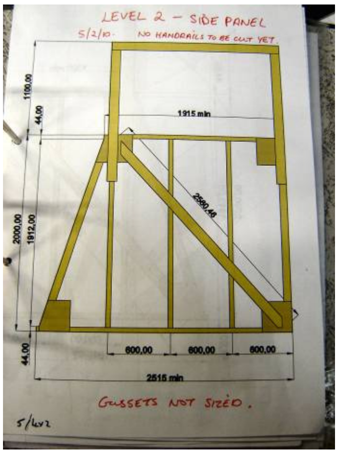

Figure 4 Design

Figure 5 Assembly

Figure 6 On Site

6. ASSESSMENT

6.1 Assessment by faculty

Students use a variety of media for submitted work. The students share two modules of Drawing and Representation in first year with the School of Architecture students. The importance of hand sketching is emphasised as both a representation and enquiry tool. A variety of pencil and paper techniques, some free hand, some with t-square and drawing board including perspective, isometric, axonometric and plan-section-elevation are taught.

The students presented their siege platform solutions using A0 posters at individual 15 minute interviews. The poster describes the concepts, the decision process (including discarded solutions) and the final solution. A guidance document discourages transcription of text and encourages thoughtful use of sketching with carefully considered annotation. Moreover, the recent Geology and Soil Mechanics project required video and slide formats with or without audio. For some short problems outputs may be in report format and submitted online via the university learning management system SULIS.

The promotion of reflective practice is informed by research literature (e.g. Cowen, 1998). To this end a learning log is used throughout the PBL process recording brainstorming, solutions and, critically, reflections or ‘thoughts about thoughts’. These are reviewed at mid-semester and general feedback is provided to the groups; final marking is at semester end.

Finally, to ensure that fundamental concepts are not missed during the group work we use an end of semester exam carrying between 30% and 40% of the module marks to assess mastery of essential fundamental concepts. The students are notified in advance of the concepts to be examined.

6.2 Self and peer assessment

Presentations and reflective learning logs are accompanied by student self and group assessment submitted online semester end using four criteria developed by the students during an early PBL session:

- Attendance
- Courtesy
- Completion of agreed work between sessions
- Engaging and contributing during sessions

To prioritise the importance of the ‘work’ component we assigned negative marks only for poor attendance and courtesy. This emphasises that these behaviours are a minimum expectation.

We have found engagement with self-motivated research between sessions uneven. However, we are promoting the desired behaviours by a weekly self assessment using a list of behavioural questions developed in Finland (Haaga-Helia, 2010).

7. TIMETABLING

7.1 Session requirements

PBL work requires minimum two or three hour sessions. There are typically two PBL sessions per week, ideally on a Monday and Thursday with lectures interspersed.

Based on previous feedback from student focus groups we structured Semester 4 with two PBL modules following in series rather than in parallel. Thus the siege problem was allocated the time of a 12 credit module for six weeks. Student feedback has confirmed a positive impact on time management. Geology and Soil Mechanics still ran in parallel but laboratory and other workload items were timetabled to avoid busy periods within the siege problem.

Where PBL is combined with significant non-PBL programme elements strong support from Departmental Heads and good collegial working relationships are required for success.

7.2 Lectures within PBL sessions

Supporting lectures designed for the specific problem may be given by lecturers not involved in the PBL sessions. Experience suggests that where the lectures are physically remote from the PBL working area attendance suffers.

Lecturers use interactive 'clickers' for multiple choice pop quizzes in accordance with good active learning practice. Students are required to purchase these clickers. Some of these quizzes are graded. The interactive display of the response frequency together with the right answer gives powerful feedback in real time to students and to the lecturer. Depending on responses, lecturers may repeat or modify material that is presenting difficulties. We find this technology an efficient and powerful teaching aid.

8. TRANSITION FROM SECOND LEVEL

8.1 PBL in first year

Moving from second level to third level is a challenging transition and facilitator awareness of the challenges faced by the students is important (Savin-Baden, 2000). Critical new habits are established during this transition. We introduce students to the PBL process in first year using the best achievable arrangement of modules and timetabling. This moves the student decisively forward into the new habits required in thinking and behaviour.

9. ONGOING ISSUES

PBL shares some characteristics with the kind of work involved in a final year project (FYP). Many university staff will have experienced the tendency of students to commit excessive time to a FYP at the expense of other modules. PBL shares this tendency. Where PBL is partially implemented this issue needs ongoing management. Facilitators may need to intervene regularly to shorten the research cycle.

Maintaining the balance between developing new habits of self-directed research and time management is an ongoing challenge for both staff and students. In this context it should, however, be noted that some students' expectation of the time commitment required in an engineering degree programme may be unrealistically low. A 5-module programme in ECTS terms has an expectation of a 50 - 60 hour per week commitment. End of term cramming was never a good educational practice. With PBL it is an impossibility.

10. FINAL THOUGHTS

The overall experience of all three authors has been energising and immensely rewarding. Students' feedback is likewise for the most part extremely positive with regard to the PBL experience. Course Director Dr. Declan Phillips, who has the longest teaching experience of the three authors, reports:

> *"In fifteen years teaching at third level, I have never encountered questions as considered and as probing as those received on the geotechnical flood defence project. For the first time I felt that I had engaged the students in soil mechanics by presenting a problem that students could see themselves encountering in their professional lives. Some*

groups exceeded my expectations with the depth and rigour of their work. Moreover, I would go as far as to say that the entire class now knows and understands more about soil mechanics and its important role in construction than they would, had I delivered the module didactically as I have for the past four years."

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ADAPTING TO ENGINEERING EDUCATIONAL AND TEACHING CHALLENGES

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Abstract: The widespread reduction in teaching hours and increase in student numbers has resulted in pressure to reduce syllabuses. The increased number of students with varied cultural background and the need for multi-disciplinary teaching in order to reduce teaching duplication and costs, introduces the need for teaching innovation and teaching methods that are effective. Difficulties are also arising in providing academic support particularly in tutorials. Even worse, a cultural situation is developing where the expected work levels for students are vague. This paper addresses these issues and looks at how syllabus contents in core engineering modules can be retained by concentrating on student self- learning. Three phases of student centred learning are proposed. First is the subject material itself and how this needs to be written and presented to the student. Engineering encompasses fast advances, new technologies and applications that need to be integrated within the modules, while still equipping students with fundamental knowledge as well as communication and interpersonal skills. The second is a preliminary tutorial system in which students, working in student centred learning groups, start by answering broadly based questions designed to test their understanding of the subject before attempting the third phase, that of solving traditional type tutorial questions. Educational advantages that merge traditional methods of engineering education delivery with new and innovative methods, are described in this paper. It also includes details on the deeper understanding exhibited by students, illustrates a greater student involvement and enhanced tutorial support, as well as staffing implications and problems encountered.

Keywords; Student-centred, small group, learning, formative assessment, diversity

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1. INTRODUCTION

This paper describes a development in engineering education where the aim has been to overcome several problematic areas arising from large student group sizes, modularisation, perceived changes in undergraduate study patterns and increased cultural diversity in the student body. The development recognises an intermediate stage in learning in between receiving information and attempting to apply it- that of actually understanding what is being taught. This has implications about the manner in which subsequent tutorial sessions are held. In this respect, the whole emphasis is placed on self-learning, aided by what are referred to as Student Centred Learning Groups (SCLG's). The paper discuses the methods tested within the subject areas of

Mechanical Engineering Design (MED) and Thermo-fluids (ThF), including the style and production of student self-learning packages and the setting up of distinctly different tutorial systems to cope with the change in learning emphasis. The benefits, to the student, the lecturer and the institution are described as are problems that have been experienced.

2. BACKGROUND TO THE CHANGES

The School of Mechanical Engineering at the University of Birmingham runs four distinct undergraduate programmes. Within the mechanical programmes "core" subjects are taught through all three or four years. Specialisation or options are offered in level 3. MED and ThF along with mechanics, structural mechanics, and control are non-optional, core topics. In the second year, the subjects are split into a theoretical study of machine elements, design practice component and ThF.

Before the current system, MED and ThF were separate courses comprising individually of a 72 hour contact time with a three hour examination. Each syllabus covered a wide variety of topics in great detail. Changes to the syllabus and the professional engineering institution accreditation requirements meant that extra material was included in the programme. This halved the contact hours for each syllabus. This reduction in time meant that a number of topics had to be taken out, but overall it was still possible to run the course in the same way. Still further rationalisation, caused by broadening the practical design and laboratory components of the course led to the theoretical elements being reduced to 24 hours. The material was taught for two hours a week for one term, with the examination being merged from MED and ThF at the end of the year, six months after the students had completed the course, not a satisfactory arrangement.

The reduction in hours then created problems which could not simply be solved by removing more material. It was recognised that certain of the easier topics could be replaced by student learning packages, with students teaching themselves backed up by traditional type tutorials. One interesting aspect of the change to part self-learning was that in the examination, a large proportion of the student body answered questions related to the self taught component. This indicated that either students were answering questions perceived as being easier than others or that the student centred learning (SCL) was leading to a better understanding of the material and a higher confidence in problem solving.

The final changes instigated as a result of the shift towards a modular system, resulted in MED being dropped from final examinations, replaced instead by a form of continuous assessment. In a similar manner thermodynamics, fluid mechanics and heat transfer were amalgamated into one course, common for all engineering disciplines and of a significantly large attendance (approx. 300). This also induced a similar replacement of part of the examinations with continuous assessment.

One of the benefits of these changes for ThF, was the reduction in staff teaching time, by approximately 60%, as a result of the duplication of repeated lectures and material for students of different engineering disciplines. The changes in MED allowed for only one hour per week for one semester (12 contact hours) to be devoted to elements of machine design. The choice was either to drop the subject altogether and pick up the missing topics in the third year course, or rethink how the most important parts of the course could be delivered to students in an efficient manner. We were reluctant to drop the course altogether as we believed that the material is invaluable for mechanical engineers.

To support the change in learning, the School increased the entry requirements of incoming students by 20 UCAS points and asked specifically for Mathematics and Physics A-Levels or equivalent. In the student's first year an additional 10 credit module to reinforce maths and physics principles was introduced, in order for the students to refine their skills.

3. CHANGES IN LEARNING

To put the changes into context, consider the situation at UoB in recent years. In 1990 there were some 40 students, in total (approximately 80% Home, 20% from overseas), per year, studying mechanical engineering. By the year 2000, this number had increased to 100 in level 2, and by 2010, to 180, representing an increase of nearly 350 per cent. The growth in students has not been backed by anything like equal increases in either staff resource or provision of housing (That is not to say however that the teaching facilities, such as audio/visual equipment and support, have not improved beyond recognition). This presents two major problems relating to lectures and supporting tutorials. From a student perspective, the large groups make tutorial sessions particularly difficult to manage. At staff/student meetings the majority of criticism surrounded the issue of inadequate tutorial provision.

A recent statistic [1] revealed that in an average undergraduate lecture in mathematics, only 20 per cent of the student group was actually following what the lecturer is saying. Most students were simply taking down the information. If this information is true then it is probably also true of lectures in engineering science, i.e. for whatever reason, only around a fifth of the students understand what the lecturer is saying. If this is so, then the "standard" lecture is a relatively inefficient means of transferring knowledge.

Many educationalists would argue that the best method of learning is to teach yourself [2]. Even if this philosophy is wrong there will be many, many occasions when one will have to learn or teach oneself. While a lecture might be a useful system to impart knowledge it often fails for a number of reasons, such as:

- Students learning at different rates,
- Language difficulties can prevent students from concentrating on the material,
- Difficulty in identifying key-points for all students (dependant on background)
- Not all students can concentrate for 50 minutes, less so for several lectures in succession
- The student might just miss that critical lecture.

Even if some material is retained, most find it necessary to re-read their lecture notes before attempting tutorial sheets. Learning by direct reading is efficient because the student learns when they want to and at their rate. We looked at replacing the traditional lecture based course by a student centred learning approach based on the following strategy:

- Replace lectures with purpose written self-study material.

- Use a few hours only to introduce each new topic, using slides and overheads to show examples. Distribute study material with instructions to read and understand it.
- Set up Student Centred Learning Groups (SCLGs), with a maximum of 6 to a group, encouraging co-operative learning.
- Divide these groups into four divisions, each division having their own room and tutor.
- Devote one tutorial session to a discussion of the material presented in the study guide. The SCLGs are encouraged to work together to explore their understanding of the topic. The self-study material is interspersed with (largely qualitative) questions to stimulate and guide this debate. The tutor is on hand to provide hints and to structure the discussion. This is efficient use of time because the tutor will always be talking to at least six students. Where common problems and misconceptions are highlighted, the tutor can address the whole class. At the end of this session, a problem sheet is distributed, typically containing six to ten numerical questions designed to enhance understanding and to develop problem solving skills.
- Devote a second tutorial session to a more traditional problem class in which students are helped with their numerical work. The students continue to work together in their SCLGs. In many cases the students can help each other to work through the questions. Where necessary, the tutor can assist a group or the whole class.
- The process is repeated with the introduction of a new topic and the distribution of a new set of self-study material. After the completion of two topics, the students sit a test. The process then starts again for the next two topics.
- The approach reinforces our requirement that for every timetabled hour the student shall put in at least another hour of their own time.
- Self study is promoted by including research (journals and technical papers) and industrial and governmental reports references in addition to standard text books. SCL is also supported by industrial visits, seminars and workshops that include both pedagogical and engineering expertises.

The approach differs from that described by [3] in that the students do not necessarily report back to the teacher, although when they do so the other groups are able to hear what is being said and so gain from seeing what alternative solutions (and problems) others arrive at. The method is similar to that of Bligh [4] in that the tutor is permitted to join the group and help in the discussions if requested. Recognition was made of the useful experience of resource-based learning (RBL) [5] particularly in respect that if you take a conventional course and simply replace some of the teaching with a learning package without making any other changes, this is unlikely to produce a very effective or enjoyable alternative. The approach taken by the authors meets the requirements of resource based learning in that the course design involved different uses of the students' time, different learning activities, different assessment, different uses of class contact and new and independent learning skills. Similar too, are the use of mainly electronic materials, written and collated by the tutors as a substitute for some aspects of teaching and library use. Our approach makes use of computers in the same manner that McDonald [6] has made use of integrating computer-based skills with functional teamwork and communication, skills embodying cooperative learning and in the way that Heffer *et al* [7] has used student centred learning developed for IT in overcoming problems of coping with the dramatic increase in student numbers.

The principal learning mechanism described in this paper focuses on full-time, campus-based students. It seeks to instil a cooperative (with both fellow students and academic staff) but ultimate student driven learning culture that exploits the understanding stage of the learning cycle, through in part use of online-based learning resources.

4. CHANGES IN UNDERSTANDING

As previously stated, a major objective of this shift to student-centred learning was an enhanced student understanding of the material presented. This is achieved by the inclusion of challenging qualitative questions in the study guides and the first tutorial session devoted to a discussion of the topic. It is the authors' intention that the questions should not impede the students' progress through the material. They are instructed to pass over questions that they cannot answer and to discuss them later in their SCLGs. Some of the questions encourage the students to challenge the statements and assumptions in the study guides. The learning material is also integrated with the tutor's personal research and research from the wider school.

5. CHANGES IN TUTORIAL SUPPORT

By organising students into small groups and encouraging them to discuss engineering topics more widely, the role of the non-lecturing tutor is extended. On traditional courses, tutors are often post-graduate researchers who are familiar with the problems on the tutorial sheets and are able to give students individual advice on mathematical techniques. Under this new system, tutors are expected to provide a deeper background to the subject as well as to coach skills. They must also be ready to intervene pro-actively rather than wait for requests for assistance. This requires a certain time overhead for the main teacher to ensure that the tutors are fully conversant with the material and that they understand the teaching objectives of the sessions. This is made easier if more than one member of academic staff is available to team-teach the subject although, clearly, this will not always be possible. Nevertheless, good tutoring is a vital component of this method - it is most certainly not the author's intention that student-centred learning in this context should be synonymous with remote learning.

6. CLASS TEST

Class tests now replace part of the examination (fully replaced in the case of MED). The tests have been designed to contain the questions on one side of a sheet of paper and for the other side to be used for the solutions. Extra sheets are provided if needed. They assess learning but also test the conceptual understanding of real life engineering problems that require both an understanding of fundamental engineering theory and the context of the actual problem. Setting the tests in this manner, means that the student cannot take the sheet away so they can be used again in the future. The questions vary in difficulty, which enables all students to provide solutions to some if not all the questions. In this way the diverse nature of the cohort can be offset (i.e. to assess fundamental knowledge rather than ability to read quickly in English). Immediately after the test is over the students are shown correct solutions. This provides instant feedback and means that marking the tests can be more relaxed. Tutors mark their tutor group using a common mark sheet. This means that marking the test papers is not an onerous task. It also indicates weaknesses in the understanding of the students, providing a positive feedback mechanism for the course material.

7. PROBLEMS

In addition to the resource problem there were some other aspects of the course that can be improved for next year. From the students' point of view the most common difficulty was lack of time to complete the material. The course was organised in such a way that each of the four topics covered was allocated the same number of hours, although some topics were more lengthy and demanding than others. The twelve contact hours were diminished by the need to run the class tests. In future it is hoped that these tests will be scheduled outside normal class hours to provide two additional tutorial hours for the larger topics.

Some students felt uncomfortable that they were not tutored by the main course lecturer and suspected that those who were might have an advantage. In future years, the main lecturer will tutor a different division each week and a set of minimum learning outcomes for each session will be agreed by the tutors to ensure a more even presentation of material.

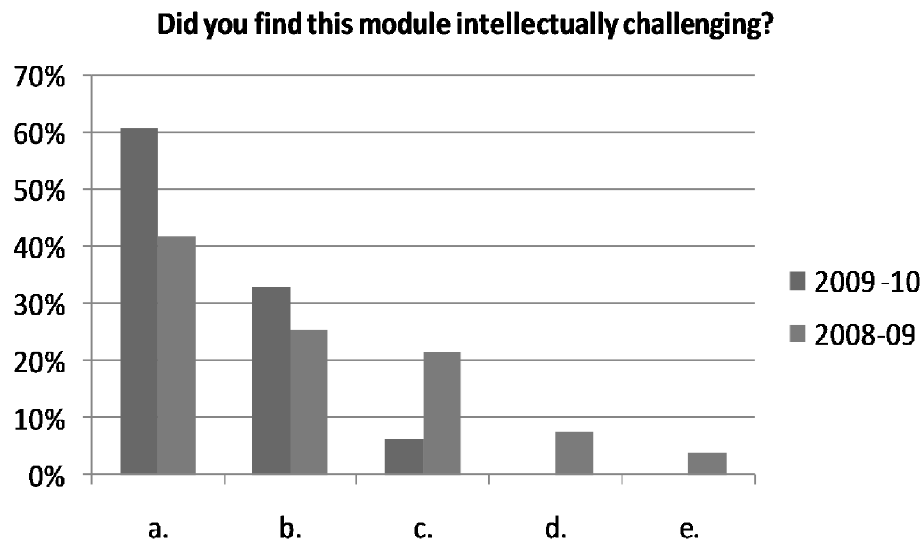
At the start of the course, some students did not prepare for the tutorial sessions and for them the classes had little value. This is in part due to the students' lack of experience of this type of learning. This lack of experience also requires that a significant proportion of teaching time must be devoted to explaining the philosophy of the teaching approach and the importance of private study. As these methods gain acceptance in the School, it is to be hoped that the students will be more accustomed to them.

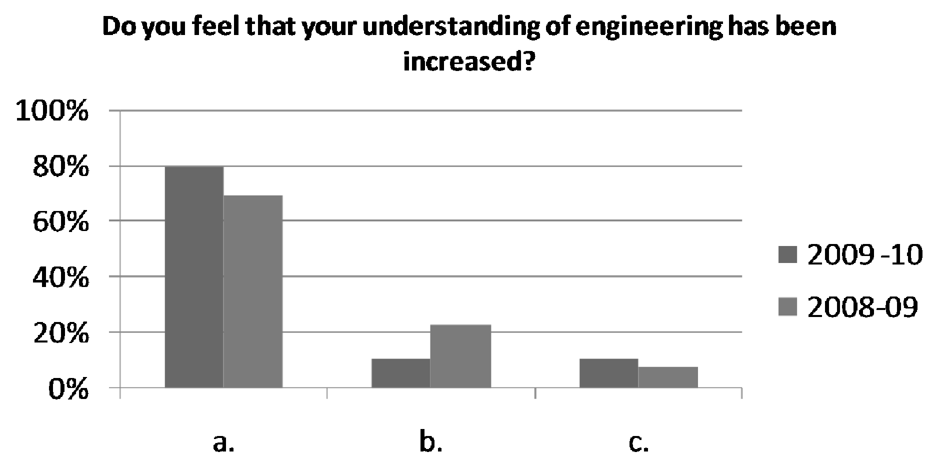
The students expected the class tests to be more difficult than they eventually found them to be and devoted much study time to revision. This reflects the mode of working encouraged inadvertently by other teaching methods - that of last minute cramming. The broadly-based class tests had the major advantage of highlighting deficiencies in student understanding. In one case, the vast majority of students revealed a consistent misunderstanding of a particular mechanism. This indicates a shortcoming of the original material which can be corrected. It also provides the teacher with the opportunity to provide feedback and correct this misapprehension. A narrower examination may not have revealed such problems.

8. FEEDBACK

A detailed post course review, in which students are questioned on a variety of issues relating to the module they have just completed (principally for QAA purposes. Results from three of the seven questions asked to students are shown below. These questions relate to in interest, understanding and intellectual content of the module.

[Relating to the figure below: **Did you find this module intellectually challenging?** (a. It was extremely challenging, b. Yes - but I coped, c. It was pitched at the average student, d. It was not at all challenging, e. No. It was a challenge to keep awake!) **Do you feel that your understanding of engineering has been increased?** (a. Yes, b. No, c. I am even more confused) **Did you find the module interesting?** (a. Yes - all the time, b. Yes - most of the time, c. Some of the time, d. Generally no, e. No)]





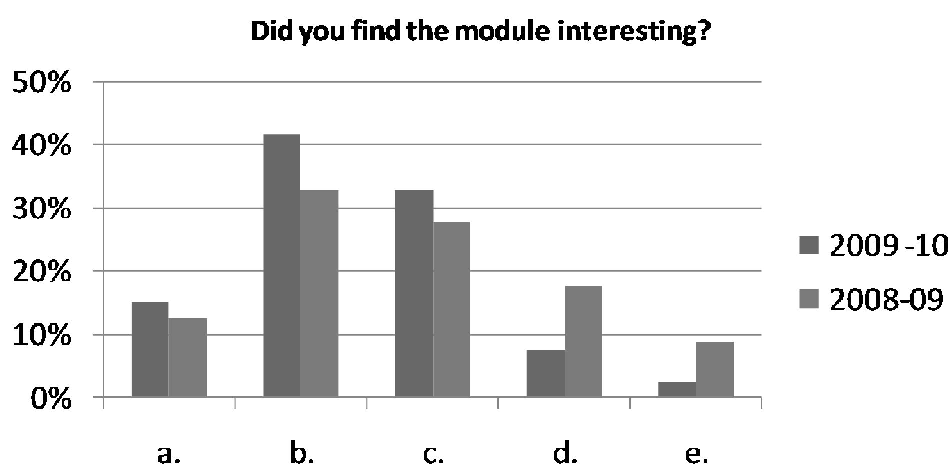


Figure 1 Student feedback comparison 2009-10 with 2008-09

9. CONCLUSIONS

Under the traditional system a lot of teaching staff time is spent on lecturing and in lectures. A lot of student time is spent on attempting tutorial questions. Similarly, a lot of teaching staff time is spent on writing examination papers, moderating and marking them and attempting to tutor, while for the students a lot of time is spent learning and revising. At the end the only feedback is the examination mark.

Under the system described in this paper, the emphasis is on student centred learning for both basic understanding of the course material as well as self tutoring. When tutorial help is needed the fact that the tutor is speaking to a group means that the tutorial advice is efficient in terms of student/staff ratios. The key finding of this renovation of teching has been:

- Contact hours were reduced without loss of content
- Teaching efficiency has increased (tutor and student time was used more efficiently)
- increased student understanding of module content (as shown by average marks increase of the mcq class tests)
- encouraged a more uniform learning process
- Post graduate tutors learn to tutor at a deeper level
- Students take on more responsibility for their own learning (students welcomed the approach)
- students liked being given the opportunity to discuss the subject and being asked broad questions before having to attempt detailed analytical tutorial question sheets,

We believe that the method leads to good learning habits. There is a more uniform learning process with less cramming because in order to achieve good marks the student must learn and apply their knowledge throughout the courses.

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CURIE TEMPERATURE IN FERROMAGNETIC MATERIALS AND VISUALIZED MAGNETIC DOMAINS.

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Abstract: The Curie temperature is a physical constant and refers to a characteristic property of ferromagnetic materials. Above the Curie temperature, a material loses its ferromagnetic properties. In a ferromagnetic material, elementary dipoles are aligned into the so – called domains and the domains – through their arrangement – bring about the internal magnetic field of the material – magnetization. At temperatures above the Curie point the ordered state is destroyed, magnetic dipoles become chaotically disordered and the material no more exhibits ferromagnetic properties. This change comes about in an abrupt manner at reaching the Curie temperature.

The paper describes a laboratory experiment intended for undergraduate students of Electrical Engineering as part of a general 1st year physics course. In the course of the measurement, students determine the Curie temperature of iron. In order to facilitate the understanding of this phenomenon, domains are visualized and observed in a microscope under variable external magnetic field.

Keywords; students laboratory experiment, Curie temperature, visualized magnetic domains

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1. INTRODUCTION

Undergraduate students of Electrical Engineering at Brno University of Technology pass the basic course of general physics in first and second semester, i.e. at the beginning of their studies. Their previous knowledge and experience in mathematics and physics are very small. Explication of the magnetic properties of materials can not start from their quantum nature. Only the description of macroscopic behavior of diamagnetism, paramagnetism and ferromagnetism is possible. Several textbooks are available. At the Brno University of Technology the textbook Halliday et al., (1997) is used.

In laboratory exercises which are a part of basic course of general physics the students experiment usually with ferromagnetic materials. They study the behavior of these materials near the Curie temperature or the effects of saturation and hysteresis during the magnetization of a ferromagnetic material. The explanation of these phenomena is not possible without understanding of the concept of magnetic domain.

Magnetic domains and their behavior under action of an external magnetic field belong to frequent questions of students. For better understanding of magnetic domains, the experiment was completed with a tool which makes the domains visible and enables to observe their behavior under changes of an external magnetic field.

2. CURIE TEMPERATURE

2.1. Magnetic Domains

Atoms have magnetic moments that determine the magnetic properties of materials. Electrons orbit around the nucleus. The orbital motions may be regarded as flows of electric current within the atom, and these currents give rise to magnetic moments. Besides of them electrons have their intrinsic spin magnetic moments.

The net magnetic moment of the atom with more electrons can equal zero. These atoms or molecules form the diamagnetic materials. The external magnetic field does not act on the material as the whole but it influences the motion of individual electrons.

The atoms of paramagnetic materials have permanent magnetic moments. By influence of thermal motion these magnetic moments are randomly oriented and their magnetic fields average to zero. In an external magnetic field B_{ext} the magnetic moments tend to align with the field. According to the experimental *Curie law* the value of the magnetization M is

$$M = B_{\text{ext}} \frac{C}{T} . \qquad (1)$$

C is called the *Curie constant,* it depends on the quantum model of respective material, and T is the temperature. Increasing external magnetic field B_{ext} increases the parallel alignment of atomic magnetic moments, and the magnetization of the material increases. When the temperature increases, the alignment is disturbed by thermal motion and the magnetization of the material decreases. This law is some approximation and it is valid only for weak fields and higher temperatures.

The atomic magnetic moments can align also without an external magnetic field. Analogous to the loops of wires with currents, the magnetic moments of atoms act each other and tend to align to be parallel. This interaction is small in paramagnetic materials. The situation differs in ferromagnetic materials. The influence of mutual interaction of atomic magnetic moments can be considered as acting of internal magnetic field that aligns these moments. The internal magnetic field B_{int} reaches great values that cannot be produced by external electric currents. According to quantum mechanics this interaction is created by spin – spin forces between neighboring atoms. Due to these forces the alignment of atomic magnetic moments arises in small regions of the material even without an external magnetic field. Microscopic magnetized regions (sizes 10^{-3} mm^3 – 10 mm^3), called *magnetic domains,* arise at this spontaneous magnetization. But the domains are oriented at random, and the material is found in a nonmagnetic state. The domains are separated from each other by thin boundary layers with the thickness of several hundreds of atomic planes where the vector of magnetization rotates from the direction of one domain to the direction of the neighboring domain. The internal energy of such arrangement is less than the internal energy of the state of complete alignment.

The domain structure of ferromagnetic materials is resistant to disruptive influence of the thermal motion. However, above a certain critical temperature T_{C}, called the *Curie temperature*, the spin – spin forces cannot maintain the alignment of magnetic moments in domains and the material becomes paramagnetic. As soon as the temperature decreases below the critical temperature, the domain structure rebuilds. The Curie temperature for iron is 1043 K which is closer to 770 °C.

Under subjecting of an increasing magnetic field two processes are caused. The magnetic domains that already are aligned with the field tend to grow in size at the expense of their neighbors and, furthermore, some domains will rotate their dipoles in the direction of the field. If all the magnetic dipoles align with the field, the domain structure disappears. The material is magnetically saturated.

2.2 Students laboratory experiment

The measured material is the transformer metal plate twisted in the form of a pipe. The temperature is measured by means of a thermocouple inserted in the pipe. The sample with alternating current I_s is placed inside of the measuring coil in its axis. The alternating current heats the sample and simultaneously produces a variable magnetic field. This field itself does not induce the electromotive force (emf) in the measuring coil because its field lines are parallel to the coil plane. However, the field induces changes in alignment of magnetic domains in the sample. It results in changes of the magnetic flux in the measuring coil, and in this way the induced emf U_i rises. The experimental setup is shown in Fig. 1.

By means of properly placed permanent magnet, the magnetic domains can be aligned for the voltage induced in the measuring coil to be as high as possible. Gradual increases in the supply current induce increase of the temperature and the resistance of the sample, and the change of induced emf, too. The emf induced in the measuring coil increases slowly until the temperature of the sample reaches the Curie temperature T_C. At that moment the domain structure disappears and the magnetic flux in the measuring coil together with the induced emf decrease rapidly. From the variation $U_i = f(T)$, the value of Curie temperature T_C can be taken at the point of rapid decreasing of the induced emf U_i. The variation is shown in Fig. 2, the temperature is in °C.

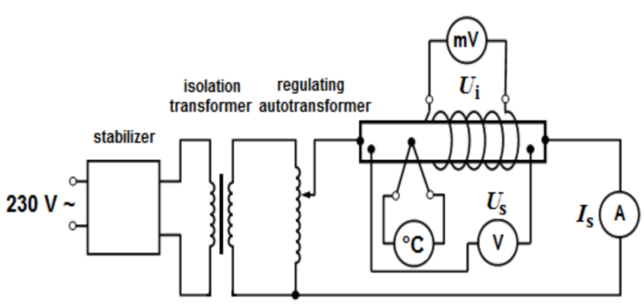


Figure 1 Determination of Curie temperature. The experimental setup.

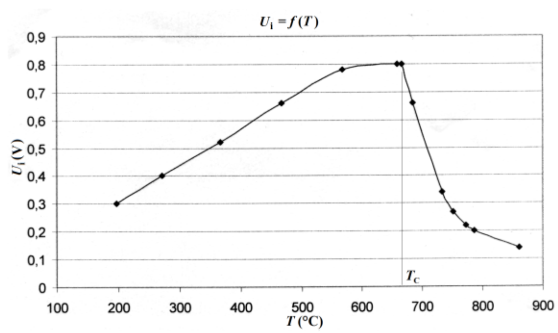


Figure 2 Temperature dependence of the induced emf U_i.

During the described measurement the students chart also the values of the current I_s in the sample and of the corresponding voltage U_s. They calculate values of the sample resistance R_s, plot the graph of the temperature dependence of the sample resistance $R_s = f(T)$, and discuss the results for the iron sample.

3. DISPLAYING OF MAGNETIC DOMAINS

To obtain the idea of magnetic domains and their behavior in variable external magnetic field, a special apparatus for displaying of magnetic domains can be used. It has appeared at European market round about 2000 in offer of the company PHYWE under the name Live Magnetic Domain. Nowadays it is possible to meet it at several websites. The University of Iowa (2010) presents the Magnetic domain apparatus including MPEG Movie. The Harvard University (2010) and the Arizona State University (2010) launch the apparatus among scientific demonstrations as the Magnetic bubbles apparatus. It can be found under the same name at the website of the TEL–Atomic, Incorporated company (2010). The apparatus of this company are used in the student laboratory at the Brno University of Technology. Made in Ireland by Lennox is given at the apparatus but it is not mentioned at the website of this company.

To observe the magnetic domains, very thin (one – atomic) layer of ferromagnetic material has been used. It is the compound with garnet structure consisting of Bi, Tm, Ga, Fe, and O. The thickness of the transparent layer is 8 μm. Due to small thickness of the layer and its composition only the magnetic domains of two types aroused. The direction of the magnetic moment in domains of both types is perpendicular to the layer surface. Both possible orientations are present, i.e. the magnetic moments of different domain types are anti – parallel.

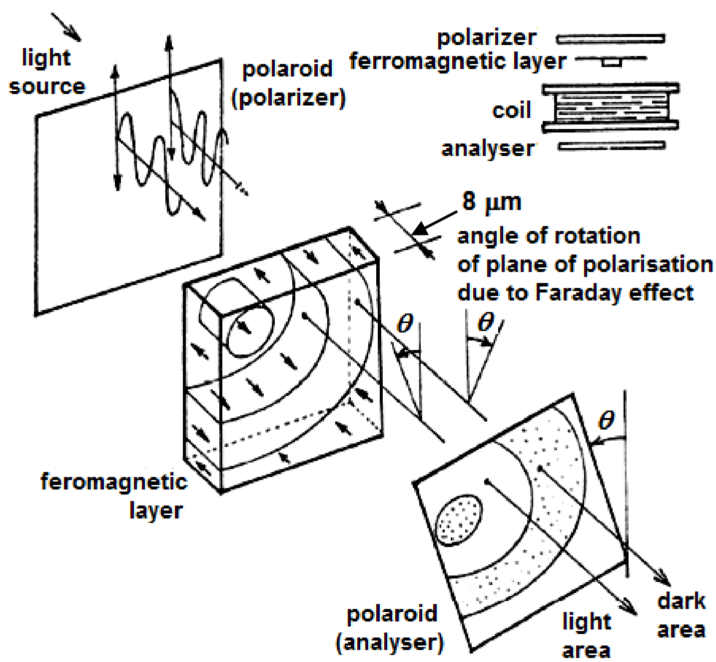
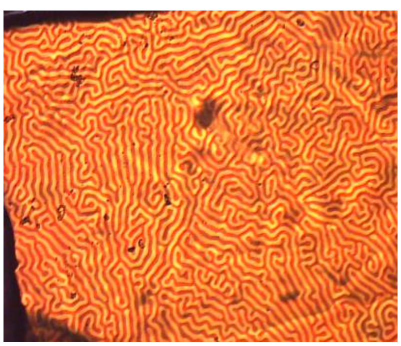


Figure 3 The geometry of the magnetic domain apparatus.

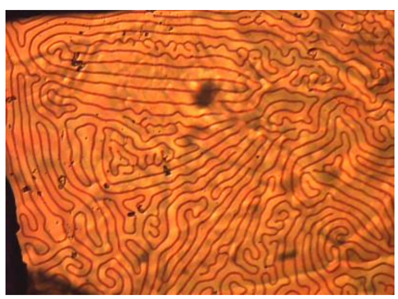
The sample of the ferromagnetic layer is placed on the coil head. It makes possible to apply the external magnetic field parallel to one or to the other orientation of the domains magnetic moment, respectively. The coil with the ferromagnetic sample is closed between two polarizing filters. The geometry of the apparatus can be seen in Fig. 3 (TEL – Atomic Inc., 2009). This figure illustrates also the principle of the magnetic domains display. The light passing the first polarizing filter (polarizer) is linearly polarized. Passing the ferromagnetic material the polarizing plane rotates at an angle θ to one or to the other side due to influence of the internal magnetic field. This rotating of the polarizing plane is called the *Faraday Effect*. The second polarizing filter (analyzer) is rotated just at the angle θ with respect to the polarizer. Passing the analyzer the intensity of polarized light passing one of the domains type decreases, the intensity of the light passing the other domain type remains unchanged. The domains appear like bright and dark areas. All parts mentioned above are closed in a metal container of cylindrical form with diameter of 50 mm (see Fig. 4)

Figure 4 Magnetic domain apparatus.

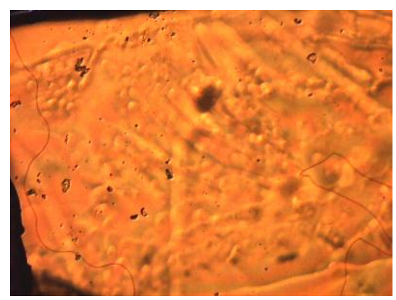
Figure 5 The experimental set up with magnetic domain apparatus.



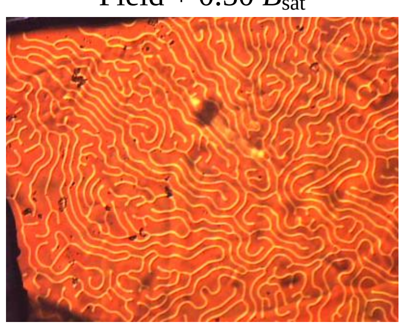
(a) The state with equal areas (light and dark) of each domain. Field 0.00 B_{sat}



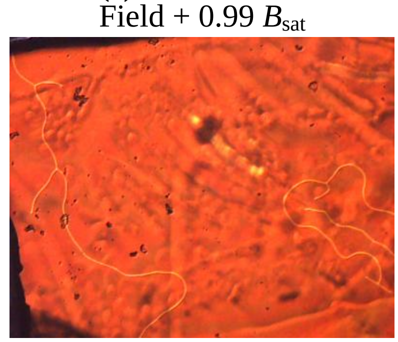
(b) Increasing light area. Field + 0.50 B_{sat}



(c) No domains. Field + 0.99 B_{sat}



(d) Increasing dark area. Field – 0.50 B_{sat}



(e) No domains. Field – 0.99 B_{sat}

Figure 6 Views as seen through a microscope x100 magnification.

The picture is enlarged by means of a microscope, recorded by a camera and displayed at the PC monitor. For increasing external magnetic field the area of domains with parallel internal magnetic field grows in size at the expense of the area of domains with anti–parallel internal field. Fig. 3 shows the situation in case the area of dark domains increases. On the other hand, after changing the magnetic field orientation the domains with bright area increase. The experimental set up in the laboratory is shown in the Fig. 5; the shots taking from the PC monitor for different values of magnetic saturation of the sample are shown in Fig. 6.

To operate the coil creating the external magnetic field, the source of controllable direct voltage 0 – 6 V, the current no more that 1A is needed. The fuse of 1A is recommended by producer. According to our experience, the coil can be damaged by long – term current close to the maximal allowed value. To secure the current limiting to the allowed value electronically and to allow passing the current only for the time necessary to follow the phenomena is very useful.

4. CONCLUSION

Teachers and students of a general 1st year physics course working in laboratories discuss the running experiment, teachers monitor if students understand the studied effect. By experiments with ferromagnetic properties of materials, teachers often find that students do not understand what the magnetic domains means. The laboratory set was completed with a tool that makes the domains visible and enables to observe their behavior under changes of an external magnetic field. Students appreciate this new possibility, and teachers find out increased student’s interest in the issue of magnetic properties of materials and better understanding of the concept of magnetic domains.

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A FRAMEWORK TO DEVELOP LIFELONG LEARNING AND TRANSFERABLE SKILLS IN AN ENGINEERING PROGRAMME

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Abstract: Engineering programmes have a strong reputation in the delivery of technical knowledge and skills. Graduates need equally high levels of competence in personal and professional skills to not only meet the existing requirements of employers and professional bodies but to also help them manage the inevitable changes that society is facing in an increasingly populated world. The need to move from traditional to student-centred learning is discussed in the context of engineering education. The use of group-based, problem driven learning facilitates high integration of technical and non-technical knowledge and skills and requires more engagement with the programme from today's student. Personal skills should be developed from a low base in a progressive, structured manner over the entire programme. A framework is presented to help those in curriculum design to develop learning, teaching and assessment methods that are in alignment with the delivery of all the intended learning outcomes in an accredited engineering programme. Through the use of group-based pedagogies, the student is required to develop a basic understanding of group collaboration skills and self-directed learning in the first year. As these are enhanced in the subsequent years, increasing attention is paid to other personal knowledge and skills such as critical thinking, creativity and awareness of ethics. High levels of direction from the tutor fade over time as the students become more competent at managing learning.

Keywords; symposium, engineering education, transformation, unsustainable, society, international.

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1. INTRODUCTION

"The world we live in demands self-starting, self-directing citizens capable of independent action. The world is changing so fast we cannot hope to teach each person what he/she will need to know in twenty years. Our only hope to meet the demands of the future is the production of intelligent, independent people" (Combs 1972 as cited in Candy, 1991).

The changes in society and environment since the industrial revolution are remarkable in scale and pace. The improvements in healthcare, education and lifestyle, predominantly for those in the western world, are an amazing achievement but have come at a price. A peak in the supply of oil that helped facilitate this transformation during the last century is imminent. Air pollution, global warming, groundwater shortages and contamination are major international problems. Yet world population and the demand for food and water continue to grow. Change, either forced or desired, is inevitable. How will these scenarios eventually play out? Engineers have always been key players in facilitating change but the model for the past may not be appropriate for the future. Can they use their creativity to treat both the causes and symptoms of global warming while retaining the benefits gained in the past? Can they communicate with and influence change in society even though many fail to comprehend what is required to resolve issues such as greenhouse gas emissions (Sterman & Sweeney, 2007)? To facilitate a move to strong sustainability, engineers will need a more holistic approach to design and development in which the entire footprint of the project is considered from many points of view through critical thinking.

For example, irrigation in farming can become the focus of creativity and brainstorming to find solutions that harness rain water instead of pumps in a move to sustainable farming. This requires critical thinking driven by an holistic view of agricultural practice. The engineer must then communicate with the farming community to agree and teach new methods. The use of many personal skills such as creativity, critical thinking, communication and people management are required, based on a set of ethics that is complementary with strong sustainability.

These personal skills are also demanded by employers and the accrediting professional bodies. Employers want innovative, self-starting graduates who can work in a team in different settings, display initiative, critical thinking and can undertake self-directed lifelong learning. Society needs these graduates to have well balanced set of ethics so they can influence policy at many levels. The Irish professional body is Engineers Ireland whose criteria (Engineers Ireland, 2007) include a wide range of non-technical skills that are compatible with the development of the above aims. Government agencies, concerned about national competitiveness and employment, can also provide input to this debate. An example in an Irish context is a recent national skills needs report which called for the development of creativity and innovation and increased use of problem and project-based learning during the third level educational experience (Expert Group on Future Skills Needs, 2009).

How should we best prepare our forthcoming engineering graduates for this new world which demands a high level of personal skills and competences? Which learning and teaching methods are now appropriate to meet a changed set of requirements for our graduates? Can we develop a curriculum that can deliver strongly on both technical and non-technical skills and knowledge? These are the issues that are being explored by staff in the School of Electrical Engineering Systems in the Dublin Institute of Technology (DIT). Our undergraduate programmes include a Bachelor of Engineering and a Bachelor of Engineering Technology in Electrical Engineering. These contain a diverse group of students including school leavers, international students and mature students with trade qualifications. An increase in the use of group-based pedagogies is being implemented to enhance the development of personal skills and competences. A framework is being developed to facilitate the coordination of these modules so the students experience a steady, progressive development of non-technical skills throughout the programme.

2. ENGINEERING EDUCATION

Constructive alignment requires the selection of learning, teaching and assessment methods that are compatible with and facilitate the achievement of the intended learning outcomes (Biggs

2003). The challenge for curriculum design in engineering education is to provide methods that are aligned with the attainment of the wide range of knowledge and skills, both technical and non-technical, that both employers and professional bodies expect a graduate engineer to possess. In many instances, however, the status quo is a teacher-centred approach to education with facilitation of learning through lectures and structured laboratories. This is the traditional approach to engineering education. Although learning can and does happen in this environment it has many limitations. Only a minority of students are sufficiently engaged with it, surface learning is sufficient and development of non-technical skills is not required. It does not provide alignment with the full range of intended learning outcomes.

In the traditional approach, students who are naturally highly engaged tend to do very well, those who are not struggle to pass, yet the former are often in the minority. Even for those, misconceptions remain unchecked (Halloun & Hestenes, 1985; Wieman & Perkins, 2005) and the passive role of the student does not lead to the development of personal competences that, combined with good technical understanding, constitute a good engineer. Technical competence alone is not sufficient; an excellent chef plus an incompetent waiter gets a bad review. Employability and key skills are often addressed by the provision of one module that specifically targets these issues but in isolation to discipline content. Such ‘professional engineering’, or similarly titled, modules can pay lip service to the wide and complex range of non-technical skills and continue to isolate technical and non-technical competences as if they are mutually exclusive and should be split apart. This does not reflect the real world.

In contrast, student-centred approaches pay more attention to the learner’s needs and abilities, achieve higher levels of engagement and thinking (Biggs & Tang 2007) and require the concurrent development of technical and non-technical knowledge and skills. Student-centred approaches include problem-based learning (PBL), enquiry learning, project-based learning, discovery learning, case-based teaching and just-in-time teaching. A review of these learning and teaching methods concluded that they encourage deep approaches to learning, improve critical thinking and self-directed learning and are based on an established understanding of how the brain functions and theories of learning (Prince & Felder, 2006). The unifying theme is that they are inductive, the problem or project is presented first and this drives the learning so that students develop questions before seeking answers. It is argued here that these methods, particularly those that use group-based pedagogies, are highly suited to engineering education. By learning through a group-based and project driven approach the students are *required* to concurrently develop technical and non-technical knowledge and skills. In this case, learning, teaching and assessment are aligned with the delivery of all outcomes, technical and non-technical. In one study, employers rated graduates from a student-centred institute much higher on a range of non-technical skills than their counter parts from a traditional institute (Moesby, 2005).

In the group-based project or problem driven approach students work in small groups of 3 to 6 members on a problem or project that is consistent with their prior knowledge. The groups follow a repeated cycle of brainstorming, self-directed learning and reporting. In the brainstorming phase, the group discusses the problem, suggests possible solutions or paths to investigate and members probe each other for current understanding. A chairperson can manage this meeting. A scribe or minute taker records any tasks or learning goals that must be addressed and these are delegated to the members before the meeting finishes. Each member then follows up on her/his task in the self-directed phase. This is the opportunity to develop self-directed learning and information literacy skills and is the equivalent of homework in other contexts. In this case, the homework is written by the student and the strategy for completing it is decided by the student. The group then meets again to allow each member to report back on new findings or information. Each member should explain in her/his own words what s/he has learnt. This is an opportunity for members to teach and question each other to enhance learning and practice communication, negotiation and conflict resolution. They are required to do so. Having addressed some or all of the issues from the last meeting, the group then starts the cycle again by identifying what must be done next, delegating the tasks and so on. The tutor is present for the meetings and observes each student's behaviour and input. The tutor receives feedback on the self-directed phase at the reporting meeting and can assess how much effort each student has made to complete her/his task. This describes the behaviour of a well functioning group. Novices do not behave in this way - time is needed to develop these skills.

3. PROGRESSIVE DEVELOPMENT AND THE ROLE OF REFLECTION

The progressive development of technical knowledge and skills has always been well defined in engineering programmes. Students are introduced to the basics in year one, the fundamental sciences that engineers apply in their disciplines. Years two, three and four deal with progressively more complex applications and uses of this knowledge. The level of maths becomes progressively more difficult, new methods continuously added. By the end of the programme, the engineering education produces a graduate who has high technical competences in the wide range of subjects associated with her/his chosen discipline.

It is argued here that the same approach should be taken for the development of the wide range of non-technical knowledge and skills. If ability to work in a team is low at the start it should be advanced by graduation. The students should progress from weak to strong communicators, team players, managers, self-directed learners, creative and critical thinkers and continually develop an awareness of ethics. These personal competences should be steadily developed throughout the programme in a progressive, structured way.

Students enter engineering programmes, at least in the Irish system, with a perception of learning that was formed during a teacher-centred secondary education. Their demand for authority is high; they expect the lecturer or the internet to be the source of all knowledge and tend not to look to themselves or each other for answers. They are weak in their abilities to work in a group, deliver a quality presentation, manage a team and so on. A modification is required for student-centred approaches to be successful but the change in behaviour takes time. It is difficult to fully assess all skills at the same time. Learning in this environment is most effective if the students have at least a basic level of group collaboration and self-directed learning. These should therefore be the initial focus of the tutor's attention. Attention can then be shifted to other skills such as creativity, critical thinking and awareness of ethics and sustainability. Figure 1 illustrates this idea but is not intended to give specific direction on exactly when, and by how much, each skill is developed. The important point is that a foundation of group collaboration and self-directed learning is laid before giving significant attention to the many other skills.

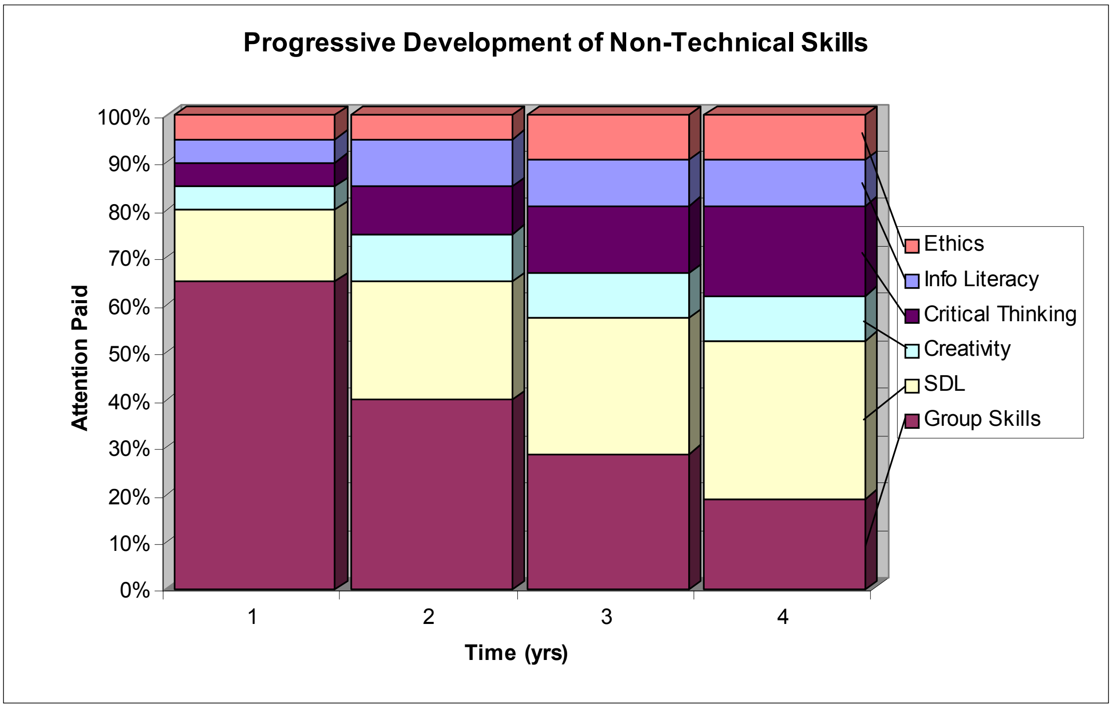

Figure 1. Change in focus on a selection of personal skills during a programme (SDL = self-directed learning)

Schön (1991) used the term 'reflective practitioner' to describe effective professionals who use reflection to cope with new challenges and situations. To be guided in this direction, student must develop a reflective practice. Reflection has a number of functions in group-based learning. It helps to improve retention of knowledge and allows the student to critically appraise her/his approach to learning with a view to improving the learning cycle (Kolb, 1984). It can intrinsically facilitate a modification in any personal competence and is therefore appropriate for the development of non-technical skills. For example, by reflecting on her/his performance in the group, a student learns to give an accurate description of how s/he behaved, analyse and evaluate this behaviour against a set of criteria and then suggest how s/he can improve in the future. For learning groups to grow in autonomy and members to improve self-management in learning, the extrinsic motivation supplied by the tutor at the start must fade and be gradually replaced by an intrinsic desire to learn in this way. This development can be facilitated through a reflective practice and requires the student to not only acknowledge strengths and weaknesses in all personal competences but to also decide how to improve. This reflective practice should also be progressively developed with criteria provided by the tutor at the beginning being gradually replaced by criteria decided by the student (Loacker 2000).

4. A FRAMEWORK FOR PROGRESSIVE DEVELOPMENT

For engineering graduates to score highly on all skills, each programme team must choose an appropriate suite of learning, teaching and assessment activities that are aligned with the attainment of these criteria. The framework presented here provides general advice on curriculum design which can then be transferred to specific learning, teaching and assessment activities by a programme team. The view of the team in the School of Electrical Engineering

Systems in the DIT is that at least one group-based project driven module in each semester of the programme is required to give sustained attention to the development of non-technical skills. A module in this case is worth five points in the European Credit Transfer System (ECTS) and approximates to 100 hours of learning, including class time. Under the ECTS system, a bachelor of engineering is equal to 240 points. It is planned, therefore, to devote 40 points to group-based learning on a continuous basis.

An important feature of this framework is the emphasis on the learning process at the beginning so students are required to work effectively in a group and manage self-directed tasks; this is faded over time as these skills are developed. This is illustrated in Figure 2.

5.1 Years 1 to 2 – 'Laying the foundation', Group collaboration, communication, learning to learn, starting reflection, problem solving

Students have difficulty working in a group at the beginning. The lack of interaction that is a common problem in small group teaching (Tiberius, 1999) must be quickly addressed. Training on group collaboration should be provided as is common in PBL in medical education (Schmidt, Loyens, van Gog, & Paas, 2007); an initial workshop is a good starting point but practice and improvement by the student is the primary objective at this stage. Groups are formed and students get a feel for group work. Assessment by and feedback from the tutor should focus on individual contribution to the group process. For it to be effective feedback should be formative and frequent and should be simple to understand; for example, tell the student one good point and one point for improvement. Students must be *required* to contribute to the group discussion, question others, offer ideas, complete tasks and report back. Tutors need a clear understanding of the learning process and self-directed learning to avoid confusion on the student's part and withdrawal from the group process (Miflin, Campbell, & Price, 1999).

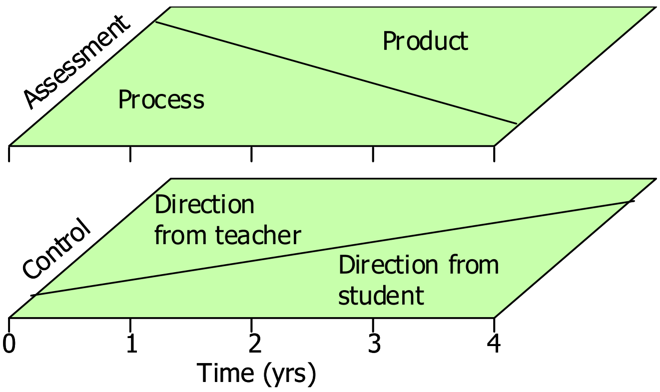

Figure 2. The change in control and assessment of learning over time (Candy, 1991; Miflin, Campbell, & Price, 2000).

Each student should reflect on learning style. For example, some students prefer to learn by doing but need to change so they also give time to improve theoretical understanding. A workshop on reflective writing should be provided in which a reflective model such as 'What?, So what?, Now what?' (Rolfe, Freshwater, & Jasper, 2001) is presented. This should be provided a few weeks into the first semester after the initial adjustment to the group environment. Reflective activities should then focus on individual performance in the group and the self-directed phase. Information literacy skills should be drawn out based on the model provided by The Society of College, National and University Libraries, UK (SCONUL, 1999) or equivalent. The goal by the end of year one is to instil some level of intrinsic motivation in the student combined with a basic level of group and self-directed learning skills to allow the motivation to have effect.

5.2 Years 2, 3 and 4 – 'Enhancing all skills', Management, communication, self-directed lifelong learning, self-awareness, ethics, creativity, critical thinking

Projects or problems should grow progressively more complex over time as groups become more effective at managing their work and members improve their personal skills. The tutor should start to observe that group meetings are being effectively managed by the students. The tutor is now fading from the central role occupied at the beginning. Improvements continue to be made. The skill of chairing a group discussion, if not introduced in year one, could be introduced now. A more defined structure can be imposed on meetings. The role of scribe, or minute-taker can also be introduced and assessed. The chair and scribe are assessed differently which can cause confusion at the beginning of year one. The students should also experience a reduction in the provision of resources by the tutor to support the problems or projects. These can be further reduced in years three and four. This requires the student to continually improve information literacy and take greater control of learning.

Making well justified decisions requires the use of critical thinking and application of creativity. Once the groups are working reasonably well, feedback on group collaboration can be replaced with feedback on critical thinking skills and the use of creativity. A workshop on these skills can be provided and the application of them subsequently assessed. The open ended nature of project or problem driven learning always requires choices to be made by individuals and the group. As students become more professional in their approach more open-ended problems can be considered such as engineering projects taken from the community. These have a real customer and help develop awareness of beliefs and values. Project management concepts and skills can also be accommodated in this model by focusing on their development with a suitable project that is not isolated from but integrated with discipline content.

5. CONCLUSIONS

Attainment of non-technical or personal skill to a high level by engineering students requires continuous attention and coordination over the entire programme through the use of constructively aligned learning, teaching and assessment methods. Group-based pedagogies, in which the problems or projects drive the learning and are set in the context of the discipline content provide true integration of all skills and the opportunity to score highly on all accreditation criteria. Personal skills should be developed in a progressive structure throughout the programme. Over time, students should become progressively more independent, problems more complex, and groups more effective so the graduate who emerges at the end is attractive to employers and has a set of beliefs and values that will help reshape society and environment.

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Innovative Technologies: The Educational Challenges

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Abstract: The creation and sustainability of a Smart Economy will require that Innovative Technologies be embraced by key stakeholders. It is therefore imperative that the engineering and scientific communities in both academic and industrial arenas be sufficiently well informed regarding the advantages and limitations of such technologies. Innovative Technologies are frequently underpinned by fundamental advances in Materials Science and Engineering as evidenced by the development and application of novel materials and structures. The goal of the activities being reported here is to demonstrate how a problem-based learning approach can be used to enhance learning of key concepts as related to the evolution and design of materials to fulfil stringent requirements in a diverse range of innovative technologies. A significant component of this work will feature the integration of technology into problem-based learning (PBL) so as to create a more flexible and effective learning experience. The ultimate goal is to enhance the understanding of, and confidence in, novel materials and structures with a view to their application in a number of industrial sectors including medical devices, pharmaceutical, healthcare, food, green technologies, aerospace, and ICT.

Keywords; innovative technologies, smart economy, education, problem-based learning, novel materials and structures.

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1. INTRODUCTION

The work reported here seeks to address a deficit in education pertaining to innovative technologies, and ultimately to the creation and sustainability of a smart economy. The Irish Government has recently published a framework document *'Building Ireland's Smart Economy – A Framework for Sustainable Economic Renewal'*, Government of Ireland (2008). As highlighted in this framework document, 'Smart economic growth recognises the interdependence between four forms of capital accumulation that drive the economic and social progress of the nation', namely, human or knowledge capital, physical capital, natural or environmental capital, and social capital, Figure 1.

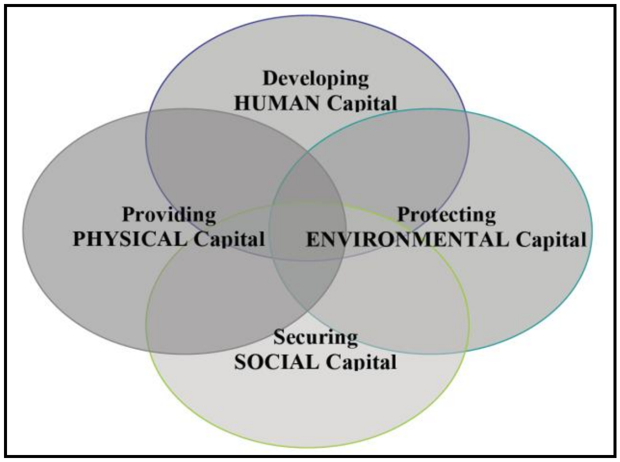

Figure 1 Interdependence between four forms of capital that underpin smart economic growth, (Government of Ireland 2008).

Central to the strategy being advocated in the abovementioned framework document (Government of Ireland, 2008), is ‘the creation of an exemplary research, innovation and commercialisation ecosystem so as to create *‘The Innovation Island’*. In order to realise this ambition, it is imperative that fundamental issues pertaining to the development of human capital and the associated implications for education be addressed as a matter of urgency.

Globally the level of funding for R&D in Materials Science and Engineering (MSE) has been substantial and whilst this has enabled significant discoveries and the commercialisation of intellectual property, the extent to which such R&D has impacted positively on educational practices in MSE and associated disciplines is questionable. Whilst students in some Universities and Institutes have undoubtedly benefited from research-informed teaching, the creation and sustainability of a Smart Economy will require that such privileges are enjoyed by the majority of students participating in programmes that underpin innovative technologies. This project, with its emphasis on the utilisation of technology-enhanced PBL, is targeted at addressing this deficit by providing students with a more engaging, challenging and rewarding learning experience.

2. METHODOLOGY

Innovative technologies are strategically important in key industrial sectors including medical devices, pharmaceutical, healthcare, food, green technologies, aerospace, and ICT, with Novel Materials and Structures (NMS) underpinning many of the more significant developments in these sectors. For the purpose of demonstrating the effectiveness of technology-enhanced PBL for education in the innovative technologies arena, NMS will be used as the initial test platform. Rapid advances in novel materials coupled with the emergence and growth of convergent technologies have served to expose the inadequacies of traditional teaching methods, particularly in terms of engaging and stimulating enquiring minds, Figure 2. The effectiveness of utilising a conventional PBL methodology has been demonstrated by a number of educators engaged in science and engineering disciplines, (Awang and Ramly, 2008; Harris and Briscoe-Andrews, 2008; Phillips, 2009; Walsh, 2007).

The methodology being employed in this work provides for a more holistic and rewarding educational experience by combining the already proven benefits of PBL incorporating innovative experimental tools, with the latest selection, simulation and interactive software capabilities.

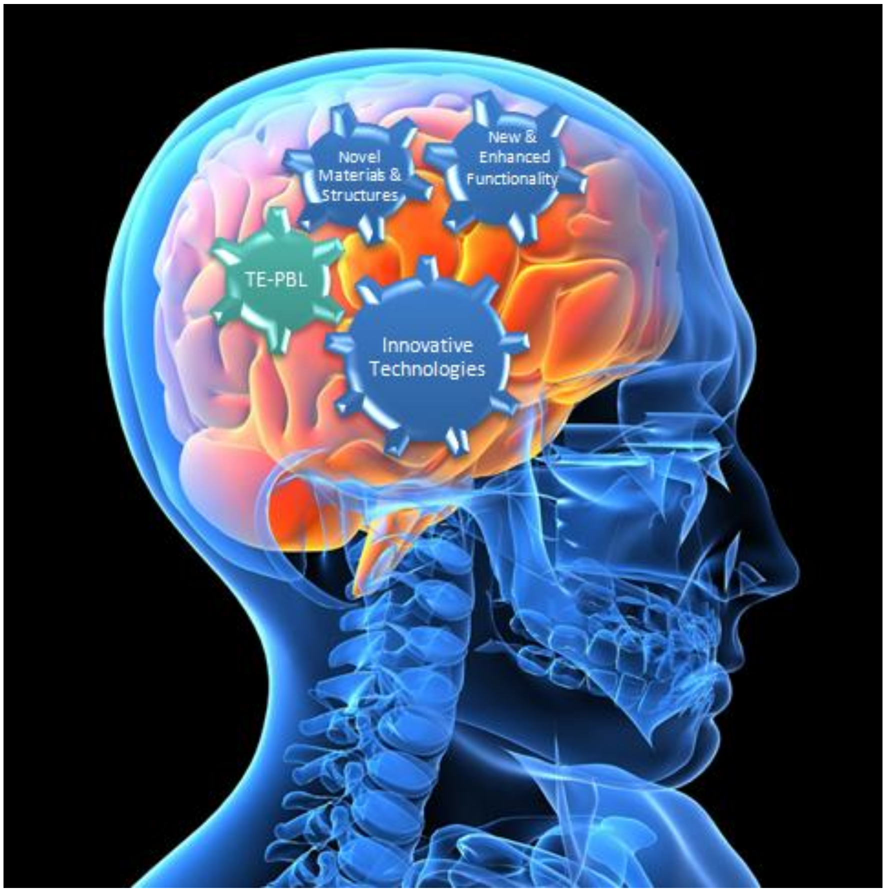

Figure 2 The Motivation for employing technology-enhanced PBL for education in Innovative Technologies, illustrated for the case of Novel Materials and Structures.

Employing this technology-enhanced problem-based learning (TE-PBL) approach to education in Novel Materials and Structures will enable the high degree of complementarity between the latest experimental and software tools to be fully exploited. The selection of the materials to be used during the initial phase has been informed primarily by the degree of novelty of the particular NMS in enabling new and/or enhanced functionality to be achieved (McDonagh and Braungart, 2002; Sanchez et al., 2005; Stuart et al., 2010). The inclusion of NMS having the potential to be commercialised as generic technologies, as defined by Maine and Garnsey (2006), has also been a key consideration. The Novel Materials and Structures being explored in the initial phase of this work include:

- Bio-inspired Smart Materials and Structures
- Shape Memory Materials
- Bulk Metallic Glasses
- Hydrogels
- Eco-Materials

The use of technology-enhanced PBL for education in these rapidly evolving Novel Materials and Structures will not only provide for a more effective learning experience, it will also create an awareness of new opportunities for technological innovations that may be achieved through the exploitation of new and enhanced functionality of products and components, the design of which is informed by quality of life considerations, Figure 3.

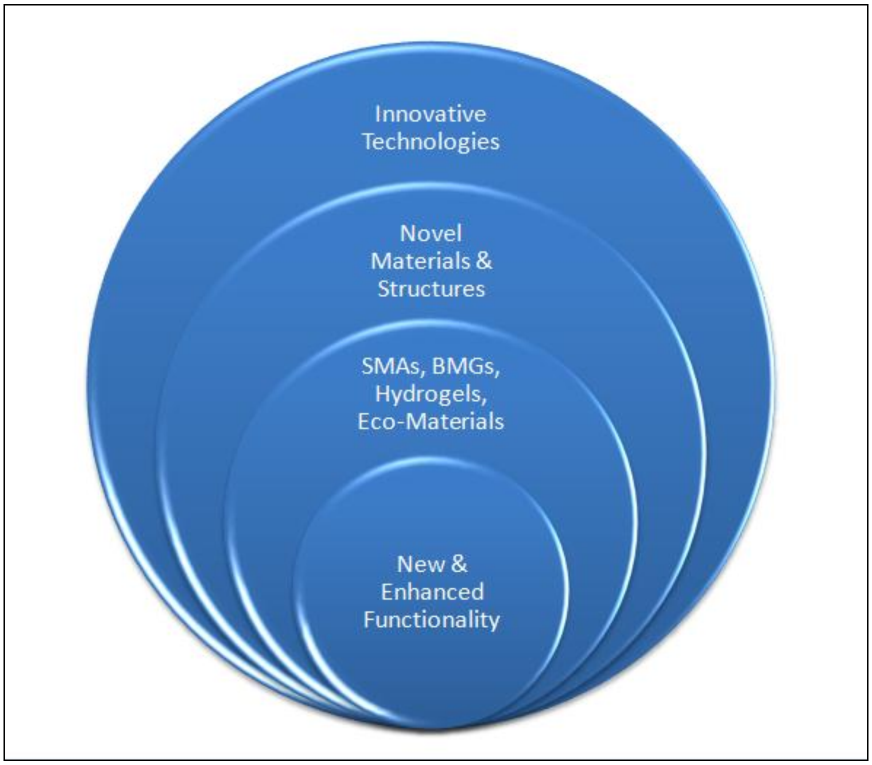

Figure 3 The role of Novel Materials and Structures in achieving New and Enhanced Functionality for exploitation in Innovative Technologies.

Whilst the TE-PBL approach is primarily being pursued in order to achieve a more engaging, challenging and rewarding learning experience for students participating in programmes that underpin Innovative Technologies, a number of very important additional outcomes are also expected to result from the use of this approach. Essentially TE-PBL utilises a set of transferable educational tools to promote Innovative Technologies and the convergence of these technologies using modern interactive and effective learning techniques (PBL and technology). This interdisciplinary educational approach is consistent with that advocated for the exploitation of technological convergence, National Science Foundation, 2002.

The technology-enhanced PBL tools being developed will be implemented by educators to facilitate lifelong learning in engineering, science and technology, whilst at the same time encouraging career paths in Innovative Technologies which are critical for the creation and sustainability of a Smart Economy.

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PRACTICAL SKILLS AND TECHNIQUES FOR THE TRANSITION TO A SUSTAINABLE FUTURE, A CASE STUDY FOR ENGINEERING EDUCATION

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Abstract: This paper seeks to assess the gap between the visions of sustainable engineering practice with its current reality. A case study involving Energetics Pty. Ltd., a leading Australian multi-disciplinary consultancy specialized in engaging public and private organizations in the development of their responses to climate change and sustainability was conducted based on a staff questionnaire developed following a review of current literature and initiatives on sustainability globally.

The results of the survey indicate that sustainability in engineering practice is still focused on the technical and financial impacts of perceived sustainable solutions. The broader aspects that have been identified as necessary have yet to be achieved in education or practice. The principle reason for this appears to lie in the perception engineers have of their practice and the ability of engineers to communicate effectively with their clients. These have combined to make regulation one of the principal drivers in environmental and sustainability engineering. A sustainability informed ethics paradigm needs to be brought more to the fore to allow engineers to engage with their clients in a more effective manner. Engineers do have the opportunity to be agents of change, but only when they envisage a broader societal role and context for engineering and can communicate effectively with the decision makers within their client organisations.

Keywords; sustainability, sustainable development, engineering education, ethics.

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1. SUSTAINABLE DEVELOPMENT IN ENGINEERING

The concept of Sustainable Development was brought to prominence by the Brundtland Commission in 1987 where it was defined as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987). Since that time the concept has been expanded by governments, business and professional organisations, each having their own particular position given their respective roles in problem formulation and decision making structures. For example, the World Business Council for Sustainable Development views the three pillars of sustainability as *"economic growth, ecological balance and social progress."* (WBCSD, 2010) Environmental organisations view sustainability as *"improving the quality of life while living within the carrying capacity of supporting ecosystems."*(UNEP/WWF/IUCN, 1991)

The engineering profession also recognises its unique role in achieving a sustainable society. The 1997 report of the Joint Conference on Engineering Education and Training for

Sustainable Development in Paris called for sustainability to be *"integrated into engineering education, at all levels from foundation courses to ongoing projects and research"* and for engineering organisations to *"adopt accreditation policies that require the integration of sustainability in engineering teaching"* (JCEETSD, 1997). This has been followed by several initiatives from peak professional engineering bodies around the world who have the authority and responsibility for accreditation of education programmes and the definition of acceptable engineering practice. The following questions arise from a review of these initiatives (see Section 4):

1. How does the view of sustainability, as held by peak engineering bodies, tally with the perceptions of those engaged in transitioning organisations to a sustainable future?
2. How have these principles been communicated through practitioners' education?
3. What aspects of practice are not reflected in these principles?
4. How might these be incorporated into engineering education?

2. B ACKGROUND OF STUDY PARTICIPANTS

2.1 Description of Energetics

Energetics is a leading multidisciplinary consultancy in Australia who has been active in the field of energy management and sustainability for over 25 years. Energetics was founded two years prior to the Brundtland definition of Sustainable Development. The activities of Energetics have changed over the years in line with the changing demands of client organisations with respect environmental compliance and best practice. Energy Management was the focus at the company's inception as cost savings and performance were clients' principal drivers. The deregulation of the electricity and gas markets made understanding energy usage vital to competitive procurement. As the climate change agenda began to assert itself in the market place, the relationship between energy and emissions became increasingly important. It also compelled companies to look at the product or service they provide in the context of its entire supply chain. This brought Life Cycle Analysis to the attention of major companies who wished to understand both the opportunities and risks associated with their product being viewed through the LCA lens. This journey, and Australia's immigrant culture, has allowed the practitioners at Energetics grow to represent a unique range of experience in temporal and geographic terms.

2.2 Participants' profile

A total of seventeen Energetics consultants with an engineering background were interviewed as part of this case study. The regions they studied in and era of education are provided in Figure 1.

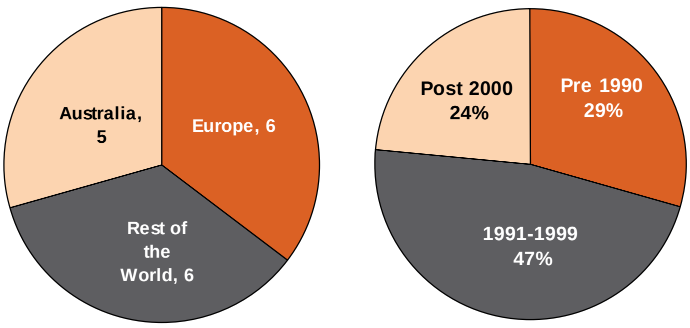

Figure 1. Geographical educational background and era of graduation of interviewees

The participants are graduates of Ireland, France, the UK, the Netherlands, Canada, South Africa, Chile, India and Malaysia. Energetics offers consultancy services across a range of areas including energy procurement, emissions accounting and abatement across commercial building, utilities and industrial sectors. The primary degree of participants (by engineering discipline) and the nature of their work at Energetics are provided in Figure 2. Engineers working for the company tend to focus on the abatement aspects of the business. This is described as process efficiency for all clients other than commercial buildings. More senior members of the company would focus on strategic aspects of abatement, which more junior staff focus on the identification and development of specific abatement opportunities.

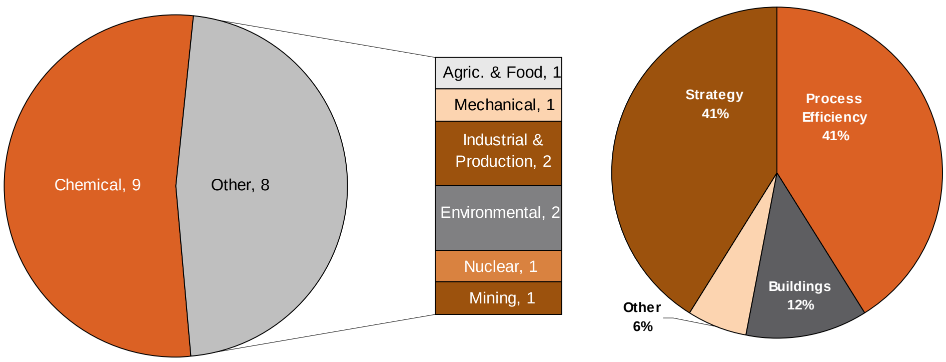

Figure 2. Primary engineering degree & nature of work of participants

Given the nature of Australian industry, which has a significant resources sector, the majority of the participants are chemical engineers, but a wide range of engineers are represented. Civil engineering is conspicuous by its absence, even though Energetics has been engaged by a variety of infrastructure operators.

4. QUESTION SET DEVELOPMENT

In conducting this case study, it was first necessary to establish what is considered to be sustainable engineering practice. In recent years national and international peak bodies from around the world have proposed principles of engineering practice as it relates to sustainable development/sustainability. These include the Melbourne Communiqué (2001), the Shanghai Declaration on Engineering and Sustainable Development (WFEO, 2004), Engineering for Sustainable Development (RAE, 2005), Sustainability and Engineering in New Zealand - Practical Guidelines for Engineers (IPENZ, 2005), National Guideline on Environment & Sustainability (Canadian Council of Professional Engineers, 2006), Declaration of Barcelona (2004), Protocol for Engineering – A Sustainable Future for the Planet (ASCE/CSCE/ICE, 2006), Engineers Australia Sustainability Charter (EA, 2007) and Guidance on Sustainability for the Engineering Profession (ECUK, 2009), These, plus a number of other publications (Gagnon et al., 2008, Stasinopoulis et al., 2008 and Ehrenfeld, 2009) were reviewed in identifying underlying themes. The following themes emerged from this review:

1. Understanding how engineering decisions impact on a local and global basis
2. Providing cultural, political and social context to engineering design
3. Incorporating information from non-engineering stakeholders into designs

4. Providing an ethical framework for engineering decisions
5. Providing balance in solutions between cost and benefits, both to the client and the environment
6. Identifying qualitative aspects that may be impacted by engineering decisions (heritage, social exclusion, etc.)
7. Participating in problem formulation, not only solutions
8. Applying a Life Cycle Costing or Analysis to proposed designs
9. Regulations – understanding them, applying them and engaging in their development
10. Capacity to explain technical/engineering issues in layman's terms
11. Engaging with non engineering stakeholders in the decision making process/acting as part of a multidisciplinary team
12. Distinguishing between "weak" and "strong" sustainability (the former allows natural capital to be substituted by human made capital, the latter does not (see Gray, 2010))
13. Recognising the importance of finding a pathway towards attaining sustainability (through for example, methods such as "backcasting") as opposed to reducing unsustainability (through for example, improved eco-efficiency)

These themes formed the basis of a structured and semi-structured interview. For each of the themes participants were asked the following questions:

a) To what degree did your engineering education address the following areas?

b) To what degree do you employ these aspects in your current work?

c) What other areas do you feel you employ in assisting organisations to become more sustainable?

d) From these other areas, do you feel any of them should have been addressed by your engineering education?

Participants were asked to quantitatively provide ratings from 1 (not at all) to 5 (comprehensively). Examples were requested for a) and b). As these questions were answered, the examples given occasionally provided opportunities for the discussion of issues related to the theme under discussion. This was particularly true of the ethics and qualitative aspects of engineering themes.

5. RESULTS

Figure 3 illustrates the average of responses from all the participants. This reveals a similar pattern between education and practice, with areas that featured in training being increasingly important in practice, e.g. cost benefit analysis and regulations. Similarly, areas that were not addressed in education appear to be of less importance in practice, e.g. qualitative aspects and distinguishing between weak and strong sustainability. This would suggest that engineering practice is influenced by training, such that individuals are reluctant to engage in areas they feel they have little or no competence.

Given that Energetics operates within the arena of climate change, it may have been expected that practitioners would achieve higher degrees of agreement with these principles. This is reflective of the fact that clients are primarily interested in efficiency and costs savings at present. Clients are exposed to the wider sustainability and climate change agendas, but the initial foothold is based on the ability to identify and achieve real savings in both emissions and cost. The nature of Energetics' business is to identify opportunities that benefit the environment, but the main challenge is to develop business cases which will successfully pass through the decision making structure of a modern corporation. These are complex organisations where many of the key decision makers are not of a technical background.

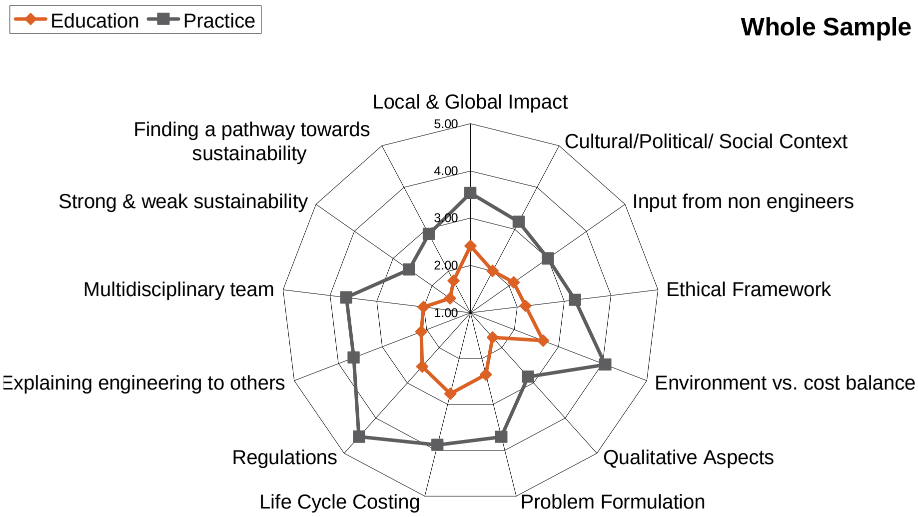

Figure 3. Ranking of sustainability principles in education and practice, whole sample

Figure 3 also illustrates the compliance driven nature of the business, with regulations being the dominant feature of practice in energy efficiency and climate change at present. These regulations are complex and interact with a range of other measures, and there was a general consensus that education did not prepare them well for this aspect of practice. The third interviewee observed: *“We talk to non-engineers, but we only talk to technical people”*. When this was put to the remaining participants two thirds agreed with the statement, with only those acting in a strategic area disagreeing. The quality of communication between the participants and these technical people was generally considered to be poor. Attempts at communication with non-technical individuals are frequently worse. Multi-disciplinary teams were only present at the strategic level, which saw the qualitative aspects of engineering decisions not featuring strongly in practice. Technical people have a preference for “objective”, measurable costs and benefits, though it was acknowledged by participants that this saw opportunities knocked back due to an insufficient business case. An appreciation for the identification and inclusion of qualitative benefits in business cases was widely accepted by the interviewees.

When discussing ethical frameworks for engineering decisions the participants were asked to consider two models of engineering practice (Bucciarelli, 2008):

- Engineers as ethical professionals with a responsibility to society at large as well as the client
- Engineers as agents of the client, bounded by their needs and requirements and the law.

Almost all respondents replied that that they considered their practice to be the latter. Ethics did not feature highly in people’s education, the exception being the Canadian respondent, perhaps as a result of the cultural norms there, where graduates may aspire to the Iron Ring, *“a reminder to the engineer and others of the engineer's obligation to live by a high standard of professional conduct”* (Iron Ring). One respondent suggested: *“Ethics are an important aspect, but there is no code of practice taught, but no indication that students at university* *are exposed to them. Peak bodies need to make ethics more high profile and an aspect of education."*

5. COMMENTARY

The inability to communicate with non-technical stakeholders has reduced the potential for sustainability in engineering practice in its interactions with modern business. Sustainability related issues do have relevance within and beyond particular engineering solutions, but a lack of understanding of the business landscape on one hand and of the issues surrounding sustainability on the other, may limit engineers' ability to make this evident to non-engineering or technical stakeholders. The perceived ethical position of engineering practice with respect to sustainability and issues of broader societal responsibility has led engineers not to try and address sustainability issues unless directed to by the client.

As a result society makes the connection betweens these groups via regulations which give engineers the license to pursue solutions within the limits set by their clients and those required by society. However, this is a minimalist and usually insufficient approach in the achievement of sustainability: it conflicts with the ECUK Guidance on Sustainability principle (No. 3 of 6) that calls on engineers to *"Do more than just comply with legislation and codes"* (ECUK, 2009). Engineers have an opportunity to broaden the client's view as they are directly addressing their needs; however they need to be able to articulate these in a coherent manner which will allow the client to have confidence to proceed. In order to be able to do this, engineers need to be able to, as one respondent put it, *"relate climate change issues to (the client's) core business"*.

Another suggested that: *"The journey we take clients on is, usually, from compliance to cost savings to novel solutions to understanding how climate change will impact on other aspects of their business"*. This requires an increasing degree of sophistication in communication and a broadening of the audience from technical to managerial and strategic actors. It is also requires a recognition that business in general views sustainability in terms of efficiency and cost savings, as this fits with the current business paradigm. This may be changing (see WEF, 2010), but it will take a significant amount of time for this to filter through the various supply chains, and not without some resistance.

One participant put it thus: *"The idea is not the problem, but the client (situation, drivers) and the timing is the problem"*. Another adds: *"Engineers may have the right technical solution for the environment, but if they cannot sell it to business, or do not realise that it is the wrong time to try to sell it, then they will fail."* This suggests that context rather than engineering is key, as the laws of physics, or the availability of a resource will not change, but the circumstances when such ideas to address those issues will. This necessitates a new role for engineers practicing in sustainability with a wider repertoire and understanding of the inherent complexity of many (human and natural) systems than is achievable through just technological know how. A broader education, e.g. taking non-technical and trans-disciplinary courses at undergraduate level, inviting lecturers from other faculties to give courses to engineering undergraduates were all seen by the participants as desirable. Increasing specialisation at increasingly early stages of one's career is a feature of a technologically driven world. At the extreme, this risks a scenario where graduates *"know everything about nothing"* (Salcedo-Rahola et al., 2008). This makes it difficult for the different specialists to communicate with each other particularly with respect to solving problems that go across environmental, social and business arenas, all areas where complexity prevails.

Some of these aspects are being incorporated into undergraduate courses at present, such as the Chemical engineering course at the University of Sydney, and other courses which allow for dual degrees, e.g. B. Eng & B.A., but difficulties of mutual misunderstanding remain. As one senior participant commented *"Social scientists and environmental scientists will not bring back engineering solutions."* The challenge here is to ensure that each discipline and expert group recognizes the strengths and competencies of others and can thus work together to chart agreed proposed resolutions. Another participant shares a more accommodating view: *"Engineers need to be able to be open and honest about the limitations of analyses presented, and …that new information will necessitate new analyses"*.

Sustainability also needs to be incorporated into other degree programmes so that there will be a common framework for discussion. Capacity building can be incorporated to a certain extent in every project, but without an underlying understanding of the issues and the potential impact of decisions, the new issues raised may be dismissed before being explored. Essentially, in order to achieved *"joined up thinking"* in the real world, universities will have to engage in *"joined up education"* which would allow key technical competencies be taught while providing sufficient understanding of their context. This will provide engineers with a sufficiently extended toolbox to be fit for purpose in engaging with society in facing up to the substantial challenges of the 21st Century.

6. **CONCLUSIONS**

Sustainability in engineering practice is still focused on the technical and financial impacts of perceived sustainable solutions. The broader aspects that have been identified as necessary have yet to be achieved in education or practice. The principle reason for this appears to lie in the perception engineers have of their practice and the ability of engineers to communicate effectively with their clients. These have combined to make regulation one of the principal drivers in environmental and sustainability engineering. This slows the development and deployment of sustainable practices in business, as regulations tend to be the lowest common denominator rather than encouraging best or innovative practice.

A sustainability informed ethics paradigm needs to be brought more to the fore to allow engineers to engage with their clients in a more effective manner. Engineers do have the opportunity to be agents of change, but only when they can communicate effectively with the decision makers within their client organisations. This necessitates a deep understanding of the context business operates in as well as being able to deliver technical information in a coherent fashion, while recognising the uncertainties inherent in analyses of complex problems. They must therefore understand complexity and the inherent limitations of an exclusively positivistic approach towards many encountered problems. Conversely other decision makers will need to recognise that in such instances engineering is an "art" and that technical pronouncements are not always final; outcome "possibilities" are in such cases more appropriate than strictly defined probabilities. This will allow the development and deployment of appropriate (re)solutions to societal issues within a sustainability informed context. As Mulder (2006) observed; *"sustainable development is not just a matter of acquiring some extra knowledge. Attitude is also important"*.

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BRIDGING THE GAP- AN ACTIVE/INTERACTIVE APPROACH TO INTRODUCTORY AEROSPACE DESIGN EDUCATION

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Abstract: The transition from secondary level classroom-based education to the university experience can prove to be a challenging experience. Many initiatives have highlighted the benefits of engaging students in active learning, and over a number of years, Queen’s University Belfast has worked towards embedding this principle into the teaching of Aerospace Design through the CDIO initiative. An introductory module, Introduction to Aerospace Engineering, has been specifically developed to bridge this gap between traditional school-based learning and the independent thought and critical analysis required in the university environment. The module is focused on providing students with a platform to develop a deeper understanding of the theoretical principles of traditional engineering subjects in a hands-on exploratory Aerospace environment. This is aimed at enhancing engagement and enthusiasm of the students for the subject, while simultaneously providing context for some of the more abstract theoretical principles. This paper highlights the ethos behind the structuring of the module, and explores how the active/interactive approach to Aerospace design can enhance the learning experience for the students through the creation of a stimulating environment for engineering discovery.

Keywords; Aerospace, Design, Education, Problem Based Learning, CDIO

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1. INTRODUCTION

The concepts of active and interactive learning embedded within engineering education have increased in popularity in recent years due to their potential to enhance the effectiveness of the engineering lecture (Prince, 2004). Active learning is generally regarded as an engagement of students in meaningful activities designed to reinforce and enhance the learning experience, complimented by periods of reflective practice. Interactive learning brings this one step further, initiating a 'partnership in learning' between the learner and both their peers and the academic staff. The ideals of active/interactive learning have been generally accepted as a positive step in engineering education, leading to significant improvements in learner motivation, understanding of principles and application of theories to the development of engineering solutions. It enables an easy accommodation of a range of learning styles as it encourages students to become responsible for their own learning. To this end, the educational process becomes largely student-centred, with academic staff becoming facilitators in the learning process.

However, time constraints and ever-evolving demands for the skills required by graduate engineers can present challenges in embedding some of the more practical elements of engineering into the syllabus. A careful balance of traditional lecture-based material, to ensure the required depth of knowledge in fundamental disciplines, complimented with sufficient opportunity to demonstrate this knowledge through laboratory and workshop based exercises is often required in order to ensure that students are both technically and practically competent on graduation. While this does not prove difficult for discipline-specific learning, this does lead to challenges in providing environments where students can obtain experience of interdisciplinary design, particularly in the earlier years of the degree courses when students have limited appreciation for the technical competencies contributing to the design process. Opportunities to engage in meaningful design exercises are essential for engineering undergraduates to improve motivation and highlight the practical relevance of the subjects that are being studied within their degree programmes (Prince, 2004, Crawley, 2002, McCartan, 2008). Practical design education also provides a valuable platform to foster creativity and improve student confidence in their engineering ability. To this end, the international CDIO (Conceive, Design, Implement, Operate) initiative presents a philosophy for reforms to engineering education in which technical fundamentals are aligned with practical learning activities (Crawley, 2002). Modern pedagogical approaches and teaching methods are adopted within flexible learning environments to enhance the overall student learning experience. It is based in the idea that reflecting on theory through practice will help to embed principles more effectively than the delivery of theory alone, leading ultimately to a deeper working knowledge of the fundamentals required for future careers.

For Aerospace Engineering, the modern Aerospace industry is evolving at a rapid rate, and it is an increasingly important requirement for graduate engineers to have a deep appreciation of the interdisciplinary nature of the design processes. It can also be argued that engineering is, in a professional capacity, a practical activity, and therefore practical training in the application of engineering theory and methods should be embedded at every level (Vernon, 2000). To achieve this in a structured manner, the transition from secondary to tertiary level education requires careful planning, as many students are unfamiliar with learning which requires this level of interdisciplinary appreciation. Care needs to be taken in ensuring that the student can clearly identify connections between interdisciplinary learning experiences and their own expectations of the degree course (often built from their previous educational experiences), and it should be remembered that many of these expectations are connected to the students' appreciation of the relevance of the subjects they are studying. To ease this transition, a new module 'Introduction to Aerospace Engineering' was incorporated in the BEng/MEng Aerospace Engineering degree programme in Queen's University Belfast to compliment both the learning requirements of a first year Aerospace Engineering student, the CDIO philosophy and the required learning outcomes of UK-SPEC. UK-SPEC defines five main categories of specific learning outcomes required for accredited engineering education (EC-UK, 2008). These are defined as (1) Underpinning science and mathematics, and associated engineering disciplines, (2) Engineering Analysis, (3) Design, (4) Economic, social, and environmental context and (5) Engineering practice.

These SLOs are designed to ensure that engineering graduates are fully equipped for integration into their future professional careers. As a significant portion of introductory engineering education is traditionally focussed on addressing the needs of (i) and partially (ii), a lack of opportunities for addressing (iii) to (v) can exist within Level 1 education (part due to the lack of in-depth technical knowledge of the students at this stage in their education). The design of the introductory course specifically addresses this concern through provision of a number of carefully structured projects introducing theory at appropriate points from the supporting core technical disciplines, providing a platform for students to gain familiarity with the principles of design, engineering practice and professional conduct, whilst practicing the fundamental science and analysis presented in the discipline specific courses. The module has been developed as 72 hours of contact time over two semesters, and is taught by two academic staff members with varying interests in both teaching and research in order to ensure that the Level 1 students receive a rounded and balanced introduction to engineering design at an early stage.

2. METHODOLOGY

The rationale behind the course design was to develop a framework to showcase the interdisciplinary nature of the design process, and to provide a platform for linking the core disciplines introduced in Level 1 of the BEng/MEng Aerospace Engineering degree programmes. Through a series of structured activities, students are encouraged to engage with engineering practice in a hands-on environment, and develop an appreciation for the design process. This is aimed at ensuring that an attachment of principle to practice in a working engineering environment is developed at an early stage in their education, and to assist in the development of a broad multidisciplinary scientific and engineering background – promoting creativity, innovation and questioning capabilities. While many of these premises are not new (and indeed, there are numerous examples of problem-based learning and design education built around the same premise), the structure has been applied successfully to immediately engage the students in the subject matter. This has manifested itself in greatly improved student attendance (maintaining 95-100% attendance across the full 24 weeks of the course), excellent feedback from the undergraduate students (with an average assessment of 4.2/5 for module satisfaction based on a 16 point assessment criteria), and general continual enthusiasm in class. A large percentage of students entering into the Aerospace Engineering programme at QUB have limited previous experience of aviation, and while they have excellent records of academic achievement, they often have abstract expectations of the technical content of the course. Additionally, students will often have mixed A-Level (or equivalent) subject combinations in their background (all students have A-Level Mathematics or equivalent), so the course is structured to assume a minimal level of prior knowledge, concentrating on learning gained through the syllabus. Ultimately the purpose is to expose student engineers to processes and procedures associated with engineering design. The course is built around a single premise – ***to enthuse and motivate Level 1 students about Aerospace Engineering in an aviation-themed practical environment.***

The educational model has been structured to provide an integrated educational environment with mutually supporting disciplines, explored through a number of aviation-themed projects. Students learn experientially to develop deeper understanding of fundamentals (for instance, Flight Mechanics, Engineering Design, Dynamics and Mathematics), while simultaneously developing skills in Design Principles, Professional Conduct, Time Management, Communication and Team Work (Figure 1). The current Level 1 programme is common to both BEng and MEng cohorts, so there is a need to ensure the course can cater to a wide range of abilities, while providing opportunities for more capable students to further challenge themselves. This is accomplished by open-ended questioning and 'discovery' based challenges, enabling students to explore concepts to a level of depth appropriate to their understanding.

As the main aim of the programme is to provide hands-on experience of the tasks and responsibilities of an engineer, and reinforce the disciplinary knowledge required to execute those tasks, a number of 'real life' exemplars were developed. This was achieved by blending complimentary groups of the technical disciplines from the Level 1 syllabus together to develop learning activities which would reinforce the learning outcomes.

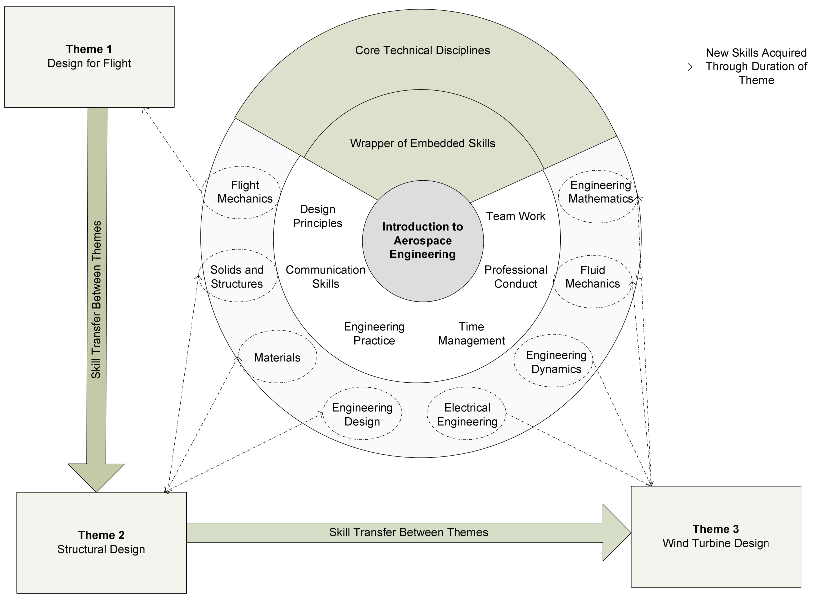

Figure 1 Introduction to Aerospace Engineering Course Structuring

Each theme is designed to (a) incorporate the theory introduced in the previous lab, and to (b) introduce new theory from additional modules in the pathway

Through evaluation of the pathway structure, these were grouped into mutually supporting activities under 'themes' – 'Design for Flight, 'Structural Design' and 'Wind Turbine Design' (Figure 1). Each theme is supported through embedded professional skills, engineering practice and design activities, and builds upon the previous theme so that by completion of the module students are fully integrating theory from all eight core disciplines together to develop an engineering solution (Figure 2). The development of these themes can be considered to be a five step process:

Step 1 Identify the Drivers Students will have prior expectations of a course which have driven the initial subject selection. A series of focus groups with current and past students enabled exploration of the expectations of Aerospace Engineering from a student perspective, and as could be expected, a keen interest in aviation and flying was central. In order to transfer that expectation into a motivator, this was used to develop the first key theme (Flight).

Step 2 Review the Technical Competencies A review of the technical competencies within 1st year was necessary to understanding when key theories are introduced. This was used to provide a basis for the discipline groupings, and determined the timing of the laboratories during the 24 week period. A review of practices (lecture and laboratory-based) was required to ensure that any activities developed provided complimentary learning activities without significant overlap.

Step 3 Development of Themes Once viable groupings had been identified, these were further developed into 'themes', ensuring relevancy to both student expectations and overall subject specific learning objectives. These were structured to ensure that students are provided with sufficient hands-on opportunity for learning about interdisciplinary design practices (with sufficient theory in the disciplinary classes to support this), and that the themes 'build' from one another to encourage a process of cyclical learning (Anderson & Krathwohl, 2001) (Figure 2).
Step 4 Review of Aims and Objectives As the purpose is to enhance, rather than overlap, with the core disciplines, a review of the learning outcomes of each theme was required. This again ensured that the course would enhance the understanding of key technical principles without introducing significant levels of overlap (and the potential for demotivation).
Step 5 Evaluation The new structure was fully evaluated against a series of intended learning outcomes defined through UK-SPEC and the CDIO framework to ensure that the educational outcomes of the course fit with those intended for an accredited engineering degree programme.

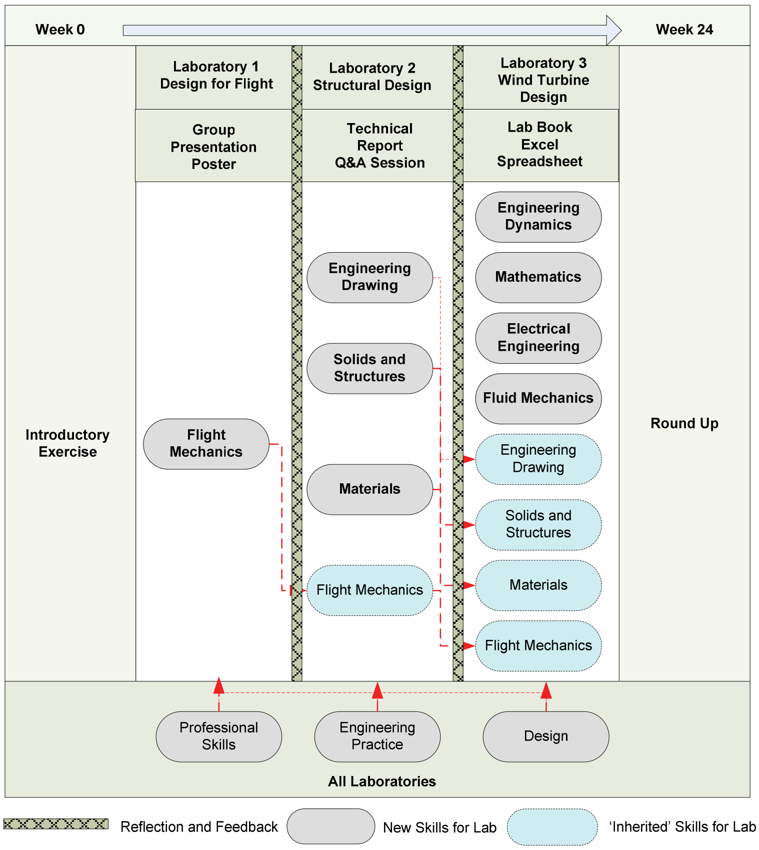

Figure 2 Course structuring for thematic progression

Once the overall structure was determined, the learning outcomes were mapped to assessment methods to ensure a balance of assessment practices across the course. The assessment reflects that problems do not necessarily have a single 'correct' answer, and is therefore based on performance - willingness to participate, how appropriate information is distilled from technical disciplines and applied to the design problem, and how critical analysis of the proposed solution is undertaken. This represents a major deviation, and is unfamiliar for many Level 1 students. A week of reflection was built-in after each laboratory and assessment, where students are provided with feedback on their performance, and encouraged to reflect, and identify the areas in which they can improve their design practices, complimented with peer review exercises.

3. COURSE EVALUATION

The outline of the Introduction to Aerospace Engineering course at QUB has been introduced, which has been successful in promoting integrated curriculum learning set in a practical environment, complimenting the CDIO principles. Students are encouraged through the exercises to work in groups to solve tangible real world problems, encouraging them to take a greater level of responsibility for their own learning. In doing this, a number of observations have been made:

Introductory Exercise The course was initiated through an introductory exercise in Week 0. It was identified as important to 'gain the students attention' as quickly as possible, and this was achieved through a design-build-fly exercise centred on a glider design. This was aimed at increasing student confidence in group work and to introduce some basic terminology associated with aerospace design. While there is no theory to reinforce, the exercise ensured that students were enthused about their choice to study aerospace early on, and introduced team-working. It also helped to introduce the academic staff in a much more informal setting than they would normally, to set the scene for the remaining course.

Thematic Areas The selection of the project themes and ensuring a gradual 'building' of material through the module is critical. The students not only gain a deeper appreciation of the technical competencies by not being over-whelmed early in the process, but also are introduced to the truly flexible nature of the engineering skills they are developing and applicability to a wide-range of areas (some of which are outside of the initial narrow view of many student engineers). The initial laboratory examined the consequences of poor design on flight operations using the School flight simulator, simultaneously introducing flight controls and aircraft design, while demonstrating the practical consequences of a poorly conceived design process. As we have found that student engineers often do not fully appreciate the iterative nature of design, a fully looped design-build-test-analyse-redesign-rebuild-retest-reanalyse proved to be an extremely successful next step for the structural design laboratory (in all instances, the students significantly improved their designs on the 2nd of these tests through careful analysis and redesign of their structures). This reinforces the idea of there being no single correct answer in an engineering design environment, and that design is a process of trade-offs. The final project, the design of a wind turbine, was selected to introduce some of the less traditional areas in which the skills of an Aerospace Engineer can be employed, embedding concepts of sustainability and social awareness into their learning outcomes, while still providing an environment in which the students could learn about the interdependence of all of the technical disciplines in the Level 1 syllabus. Through a gradual build up, the students were encouraged to use and re-use skills developed in the core modules in their exercises, with less formal guidance given as the modules evolved in order to promote creativity and ownership. It was also noticed that they became more aware of the links between the design exercises and their theoretical modules, were identifying theories/concepts which may help and understand the importance of brining notes from their other classes to the design labs.

Reflection and Feedback All students were encouraged to reflect on their performance in the laboratories, introduced in a staged manner. The 1st laboratory, due to unfamiliarity of the students with this type of exercise, was facilitated by the academic staff through questioning, asking them to identify areas of new learning, and how learning from technical disciplines mapped to what they understood about the design process. In the second laboratory, this was extended to students being questioned by classmates about their designs and experience. For the final exercise, the students personally reflected on their performance, and how they could improve both their technical and interpersonal skills in future projects. This reflective practice was complimented with feedback from the staff (both during the laboratories to provide guidance, and also during the question/answer sessions). This not only encouraged personal reflection, but also to promote giving guidance to their peers, based on their own experience. The success of this gradual approach was evident in the written submissions, which evolved from purely factual through to more descriptive, mature evaluations of the work undertaken as the year progressed. To round off, small focus groups were held with the students to compliment the more formal module review processes, in which students were encouraged to identify areas for improvement in both their approach to design, and to the module structuring we has devised.

Professional Skill Development Complimentary development of professional skills - groupwork (exercises are undertaken in teams, and teams rotated), reporting, communication, time management and engineering responsibility are embedded into all of the exercises undertaken during the course to reinforce the professional nature of engineering.

Inability to function in groups One of the major challenges which needs to be overcome is the lack of prior experience in group work the majority of students have. While many of the students are highly capable and can work to a high level autonomously, they struggle with some of the more socially-oriented skills required for professional working environments – in particular time management, conflict resolution, communication skills and the ability to equally distribute workload between group members. This was resolved in the 1st exercise by concentrating on the development of these core professional skills integrated with one supporting technical discipline. In most instances, the students demonstrated a greater awareness of how to allocate work between members and communicate more effectively by the 2nd project, and the greater sense of community in the teams alleviated most of the time-management and conflict resolution issues. By continuously refreshing the groups, they were provided with multiple opportunities to experience new team formation. By the third exercise, it was clear that the students had a much more mature approach to this and were able to identify the need to assign team roles for themselves with minimal (and in some cases, no) guidance.

Unfamiliarity with the process of design prior to tertiary level Based in many of the preconceptions from secondary level education, students are often focused on the concept of the 'right answer', and many struggle with the idea that there are multiple correct pathways to choose in a design environment. They are unfamiliar with taking initiative, and more at ease with following instructions to develop 'the solution'. Planning actions within design is also not well-formulated, and often the students are not capable of anticipating problems with design or embedding concepts of risk (for instance, assuming that all team members will be available for each week of the project). This was again addressed in the 2nd exercise by introducing an iteration into the design process to demonstrate that planning can reduce the number of problems, and that 'emergent' behaviour within the design process is something that they should be aware of (not everything will always go as planned, and that risk analysis is important).

Uncomfortable with interdisciplinary analysis There was limited understanding of how to apply knowledge from a number of disciplines to an engineering design problem. This was facilitated by increasing the number of disciplines required from project to project to prevent overwhelming with the quantity of information they were required to process and to guide them gradually through both technical and professional skill development. By the 3rd exercise, students were identifying relevant theoretical concepts from previous/current modules without guidance (understanding that this was expected), indicative of a maturing in their approach.

Absenteeism and motivation Absenteeism and lack of motivation is endemic in Level 1 engineering classes, and can in part be attributed to a complete lack of motivation on the part of the student (something that was widely reported in the focus groups undertaken). However, over the last academic year with the implementation of the new course structure, absenteeism has been reduced to almost zero, with virtually 100% attendance at each class over both semesters. Students have reported enjoying the class, and linked this to their attendance.

Instructor integration with class Through working in a student-centered learning environment, the two lecturers became more aware of many of the learning barriers and issues of individual students, more so than in a normal lecture/laboratory environment. In many instances, issues with individual students were identified more quickly than otherwise would have been, and a higher level of engagement with the students was achieved. This is tightly linked with the need for the supporting academic staff to fully embrace this change of educational environment, again significantly different from that traditionally encountered in Higher Education.

4. CONCLUSIONS

The Introduction to Aerospace Engineering module has successfully provided a platform for students to gain experience of the engineering design process while simultaneously developing an appreciation for some of the challenges which face the professional engineer in their working environment. It has also enabled the lecturers to understand more about the way in which new student engineers assimilate and use engineering information to make judgments in the design process, and how to facilitate increasing the maturity of how they approach this. The model which has been developed progressively introduces students to the ideals of interdisciplinary design while encouraging professional skill development, and fits with the ideals for learning outcomes and programme structuring set out in UK-SPEC and CDIO.

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Qualifying Energy's Value to Future Engineers and Scientists

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Abstract: Using our academic research and teaching modules for chemical engineering and environmental science undergraduate students, we present a method for laying a foundation for students to understand energy's value in the 21st century more robustly and within the context of both the developed and the developing world. In this paper we argue that coming transitions will be supported primarily not by new technologic inventions or discoveries, but by matching systems to consumption patterns and vice versa. It will be a societal transformation, which relates to limits, timeline, and geo-social context. First, we present data on the saturation-like character of the relationship between human development and energy consumption, and couple this with a Maslovian assessment of the pyramid of human needs. Second, we engage students to explore the role of alternative energy solutions, to also understand the values the energy systems seek to meet, which is a function both of where the society is on the energy versus human development curve and of timeline issues. Third we address timelines as they relate both to issues of depletion and to technologic maturity and urgency. Just as the depletion place limits on the sustainability of fossil fuel-based energy systems, technologies that require fundamental science breakthroughs are unlikely to be solutions to imminent shortages. We need to understand the realistic range of peak oil occurrence timing in juxtaposition with an understanding of the time-to-market of alternative energies. This equips engineering students to bring their technical expertise to bear on qualitative problems of human development.

Keywords: engineering education, energy, unsustainable, society, international

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1. INTRODUCTION

The world is facing sweeping energy transitions based on three challenges: (1) to mitigate environmental impact; (2) to reduce dependence on depleting resources; and (3) to increase access to energy for the still-developing half of humanity. In order to make informed decisions to advance effective energy transitions, strategies must be well-informed of the real values and costs of energy sources and systems. Energy is too important, too broad, and too complex for simplistic, compartmentalized, disciplinary stratagems. It permeates virtually everything we use and do. Whether we embrace the transitions proactively or attempt to hide our heads in the sands of unlimited growth optimism, we will find ourselves in the midst of a sweeping energy transition within the next few decades. This requires the ability to compare alternative energy systems on common basis. We must develop strong, effective communication between technical experts and social science experts, the public, and the politicians that represent them. At the same time, engineers working on technologies for sustainability must be able to understand the social contexts and the needs their technologies are meant to serve. There must be dynamic processes of technology and social sciences informing each other.

There is a growing consensus that the resilience and sustainability of critical infrastructures will be threatened this century and that the next generation of engineering professionals will be ill-equipped to deal with that. It is imperative to understand the values added to these systems by the current energy inputs. One great challenge is the sheer magnitude of energy provided by oil, gas, and coal currently. As these resources struggle to keep pace with global demand, all systems will be stressed and it will be important to optimize energy mix solutions based on a variety of resources available. To broach these issues with students, we consider the place of energy systems in relationship to a number of infrastructural systems. Educational planning and transformation will be essential to the resiliency of changing energy systems.

We suggest that it is important to create a set of interwoven curricular models to develop new paradigmatic approaches to understand energy and its relationship to other critical systems in a more comprehensive fashion to: 1) assess the baseline energy requirements of critical, interdependent infrastructures needed to meet scalability, sustainability, and resiliency criteria in response to perturbations in the energy supply chain; 2) evaluate the real energy value added by the entire portfolio of energy technologies (both proven and speculative) in the form of goods, services, and environmental impacts they produce, all affecting infrastructures. Ultimately, the goal is to train energy professionals to understand energy using a systems approach and to think critically about the potential energy gains of new technologies in comparison to the reduction of energy inputs for stable infrastructures.

2. A NEED FOR MULTI-DISCIPLINARITY

How best do we educate students about relationships between energy use and the living and non-living world? The pervasive disciplinary educational infrastructure presents a challenge in addressing innately multi-disciplinary issues. We propose systematically connected training across disciplines to enable students to engage the issues effectively. A robust understanding of the linkages between critical infrastructural systems is an essential step to achieve a more sustainable society, whose systems can respond resiliently to changes in resource supply chains or other critical systems. Since major economies depend on energy imports, we cannot ignore the impact of global stress factors on resources. With modern energy vital to every sector of the global economy and social support systems, the potential disruption caused by a forced transition from abundant energy supplies may be the defining challenge of the coming decades. Meeting this challenge demands an informed understanding of the challenge and impacts on related systems. It will also require a workforce capable of grasping the complexities of inter-related systems, and solutions dependent on social and resource contexts.

Peter Reason discusses how we have come to our present modern worldview, one which obscures the crises of sustainability, justice and poverty. These demand, he writes, that we see ourselves as participants in the planet’s life systems (Reason p. 6). Others have also discussed the need to change our energy education (Dias, 2004, Orr, 1994). Emerging professionals must be equipped to evaluate the energy linkages of infrastructures and understand the needs being served. How do we best provide students with the critical, creative and futures thinking skills to develop innovative and alternative solutions to sustainability issues? There is value in connecting the technologies studied to the needs they serve.

We suggest a cross-disciplinary approach to teaching, in which engineering interacts dynamically with health, regional and social sciences. It stands to provide educators as well as students with a greater understanding of the linkages between critical infrastructures and an example of a new pedagogical paradigm to incorporate broader, more systemic thinking into students, from the early grades, through professional training.

It will be essential to characterize the linkages between critical infrastructural systems in pursuit of more resilient and sustainable criteria. But it will be difficult to develop a robust, high-level understanding of complex systems. Since its inception, the scientific method has been widely successful at dissecting problems into ever smaller components. As we have created classifications and taxonomies, we have also created increasingly narrow specializations. While specialization has been crucial in allowing tightly focused research to penetrate the minutest levels of reality, it has also served to isolate inquiry from the whole of reality, subjugating high-level interconnectedness. With looming crises in the sustainability of our use of resources, we are confronted with the need to understand the whole of reality and the interconnectedness of systems. It is exceedingly difficult to build such understanding by reassembling the tiny pieces we have dissected into sub-specializations. To this effect, a paradigm shift is called for in educational and engineering practice toward more comprehensive analyses that view linkages between systems. While there are inter-disciplinary engineering programs emerging globally, the American academy certainly remains dominated by disciplinarity.

Our experience finds students to be highly motivated by the challenge of applying their work to important problems. They bring valuable creativity to the task. Since students are less indoctrinated by years of practice in the status quo of disciplinarity, they are prepared to employ – and to engage in developing – new paradigms to address innately inter-disciplinary problems.

3. WHAT CONSTITUTES A VITAL HUMAN NEED?

How do we reconcile the range of what people consider as vital needs? One way to do so is to recognize a hierarchy (or continuum) of needs, some of which do not come into play until others have been met. Abraham Maslow suggested five hierarchical levels of need that we use as a launching point to class discussions, which are:

1. Biological and Physiological: food, water, air, warmth, sleep and procreation. These are instinctive and critical to survival. Other desires are secondary until these needs are met.
2. Security: protection from the elements, predators, enemies, disease and uncertainty.
3. Belongingness and Love: family, friendship, and community are important at this level.
4. Esteem: people seek esteem, including: the desire to achieve and accomplish, to assume responsibilities, to build personal worth and status, social recognition and reputation. Quality of life becomes particularly important at this level.
5. Self-actualizing: the need to find meaning and purpose in life and realize one's potential. Here, people seek rewarding employment, spiritual exploration, and personal freedom.

We find the idea of an evolving progression of needs helpful as we take on the question of energy's role in meeting vital human needs.

3.1 Energy and Maslow's Hierarchy

Energy does not directly feed, house, or clothe people. But energy services facilitate the production of food, construction materials, and textiles. The "causal chain" leading from energy resources to improvements in people's lives can be long and complex, requiring many other non-energy inputs. Moreover, energy services often bring improvements in several areas at once. For example, consider all the uses to which electric power can be directed: lighting, refrigeration, communication, use of appliances, cooking, space heating and cooling, and even transportation.

So, while the link between energy and development may not be obvious, energy can be shown to be a basic necessity for human activity and economic and social development. For example, wide scale poverty cannot be overcome without moving up the so-called Energy Ladder. The Energy Ladder concept claims that given the opportunity, people naturally gravitate to energy systems that improve their standard of living. They do not have to be persuaded. When a system is more effective, safer, cleaner, more convenient, and affordable, it is adopted rapidly. Most Energy Ladder discussion focuses on residential energy use because household fuel (particularly cooking) demand makes up more than half of total energy demand for much of the world's poor. Raw biomass fuels are on the bottom rungs while solar and wind is at the top. Moving up the ladder, energy resources generally become progressively cleaner, more efficient, more technically sophisticated, and more expensive.

There is rarely a wholesale transition from one rung to another. No single energy source or technology can supply the breadth of energy inputs required to meet all applications. Wind and solar can provide clean efficient electricity, which is essential for many purposes, but for cooking, charcoal is a more readily adapted improvement over raw firewood. People assimilate new fuels and new technologies depending on what they want to do. In turn, new energy systems open up new applications. The progression from primitive subsistence to industrial/modern societies demands increasing energy inputs as well as new technologies for agricultural, commercial, industrial, transport, and public services, as well as household cooking.

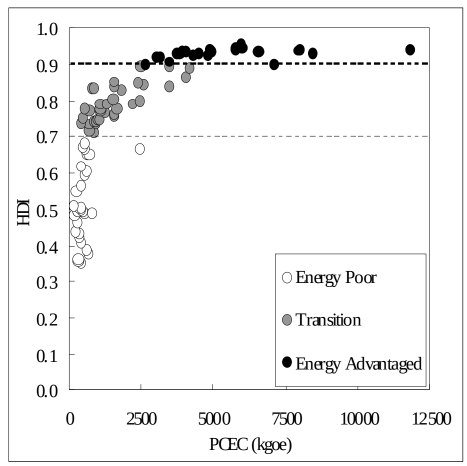
Increased demand for energy is thus a function both of increasing population and of demand for more energy to meet higher level needs. This is both a technical and a social challenge. Combining the issues of energy use and infrastructure requirements, the five different Energy levels in Maslow's hierarchy of needs then look like:

1. *Biological and Physiological Needs.* In order to meet survival needs, food must be secured, distributed, and processed. Pure water must be delivered. Housing must be built and heated. Energy is expended in all these tasks - raw biomass provides minimal use.
2. *Security Needs.* Energy can light the dark, preserve foods, and enable production of goods. Societies that are able to employ energy in more sophisticated ways can enhance their security, but still may not be able to achieve development.
3. *Social Needs.* Communication, transportation and the building of public infrastructures become important in meeting social needs. Modern energy has facilitated large numbers of people to have their social needs met in addition to their biological and security needs.

4. *Esteem Needs.* Quality of life rises to the fore once social needs are met. Education and other public services become important. The environment starts to receive attention.
5. *Self-actualizing Needs.* Although some have reached this level throughout history, self-actualization is yet to be seen by whole societies. This will be possible when most people in society enjoy a high quality of life, with very few poor. (Ebenhack & Ebenhack, 2007)

4. ENERGY CONSUMPTION AND QUALITY OF LIFE

There is sufficient evidence to suggest a causative role for energy in affecting the resiliency and sustainability of the other basic infrastructural systems mentioned above (Goldemberg, 2001; Pasternak, 2000; Smil, 2005). Modern energy is requisite to schools, hospitals, and waste treatment systems. With judiciously targeted changes in policy and practice that promote broad access to locally-produced modern energy, the potential exists to achieve significant development in “Energy Poor Nations.” This can be done with modest investments in their own energy sectors, utilizing a local energy mix.



Main themes that we highlight to students:

1. The Energy Advantage Relationship. Comparing the UN Human Development Index to per capita energy consumption reveals what we call “The Energy Advantage.” This links quality of life to energy consumption remarkably well. The poorest nations do not consume enough to accommodate the most important aspects of development: mechanical power; refrigeration; lighting; transport; and communication.
2. Modern versus Antiquated Energy Sources. Most of the Energy Poor Nations lack access to modern fuels, leaving them dependent on inefficient, unhealthy, and development-crippling raw biomass, like firewood. The data show that the more a nation depends on raw biomass, the lower the quality of life its people can expect.
3. The Energy Export Curse. Some developing countries rely on energy exports. The data show that major energy exporting nations have lower qualities of life than nations purchasing their energy resources.
4. Energy Security. The problem isn’t that Energy Poor Nations lack resources, it is the lack of capital and experienced professionals to develop modern energy for their own benefit.
5. Small Investment, Huge Payoff. Theoretically, little additional energy is required in Energy Poor Nations to increase quality of life substantially.

5. VALUING ALTERNATIVE ENERGY SOULTIONS

The practical reality of energy use is that consumers do not use joules, they use services provided by energy: transportation, heating and cooling, lighting the dark, cooking meals, etc. Valuing energy provides perspective and allows us to consider energy within the context of the needs it meets, the services it provides, and the impact it has on our way of life. So, we seek to measure not the quantity of energy contained, but the value added by the energy resource. Students focus on the effective end-use energy delivered to the consumer and the costs, or value reductions, to provide such energy. There are a number of factors to consider when determining the value of energy, including external factors that remain largely unaccounted for in energy-cost analysis. Factors to model an energy resource's real value content include: energy resource viability; energy economic viability; technical viability; social acceptance (education, cultural appropriateness); environmental concerns; health and safety.

As described by Ebenhack (2007), the proposed model conceptually looks similar to those developed for assessing value-based pricing (Feldman and Wusrt, 2001). The primary result of the model, then, is calculation of a real energy value added (REVA) index that is, essentially, a coefficient to be applied to a specific energy resource (e.g. oil, coal, solar, nuclear) to assess true energy value. The starting point is a diagram for energy source value and assumptions upon which to model future changes. REVA introduces students to traditional life-cycle assessments (LCAs) (Friedrich et al., 2007; Kara et al., 2007; Land et al., 2007;Osman et al., 2007), including 'emergy' calculations (Odum and Brown, 2007) and critical thinking about calculations and algorithms for quantifying the more social-connected variables. This engages students in assimilating information broadly across disciplines in the context of an analytical project and in critical thinking in the face of analytical uncertainty.

5.1 Assessing Timelines

The urgency is both an impending shortage of petroleum and the need to expand energy options for the world's poor. In some ways, oil and gas represent 'alternative energy' to fuelwood-dependent people, but adding oil and gas to their energy mixes must include plans to address the increased competition for those resources over time. Likewise, the 'renewable alternatives' need to assessed within a context of the role that each can play and in what time frames.

The transition toward more sustainable energy systems will not be simple. Maturation times are required for innovative technologies to move from the laboratory to demonstration scale, and on to commercial scale. Historical analogies can supplement the assessments of technologic options and how rapidly they can be adopted in various contexts. This, again, requires understanding social contexts. Many note that the developing world is 'leap-frogging' directly to cell phone technology, skipping the step of land-based telecommunications and its infrastructure. To what extent can the developing world skip over the fossil fuel step in energy development? Can a move toward more decentralized energy obviate massive infrastructure investments? Can the adoption of new energy technologies be accelerated? How do consumer preferences in the affluent world challenge the rapid adoption of new energy systems? Understanding the transition toward more sustainable energy systems involves future studies, which inevitably calls for historical analysis, layered with the other technical and social science disciplines.

5.2 Example: A gigajoule is not just a gigajoule

In conventional analyses, it is all too common to compare energy units without considering their effective use, let alone externalities. Similarly, engineering students are conventionally given some exposure to basic economic analyses. We suggest that Sustainability demands systems-level thinking. To introduce this in the classroom we have also introduced several applied, project-based energy and sustainability courses at the University of Rochester and the University of Southern Maine. One technique that we have employed is to have students identify the context and/or clientele for technologies they select to investigate. This requires them to think the application and the consumer, drawing them into social science and/or humanistic concerns.

Several of the courses we have introduced are cross-listed, to encourage a diverse enrolment. We try to encourage groups to form with multiple disciplines represented, but that has not been as broadly successful. In part, there seems to be some challenge in convincing non-technical students that a course with an engineering listing will not be prohibitively technical for them. Thus, we have commonly found imbalanced registrations, making it difficult to comprise mixed teams. We believe that this issue can be addressed through diligent publicity efforts (and in the long-term, word-of-mouth from former to future students can help this.) We consistently try to be open to supporting the direction student interests take – we offer suggestions and some direction, but not in proscriptive fashion. This has been very successful in encouraging highly motivated student efforts, but intrinsically prohibits ensuring any desired mix of disciplinary backgrounds, as students select their own groups, around projects of interest.

In one course that relates to evaluating the environmental footprint and options for enhanced sustainability on the campus and in the local community, the groups are required to identify ‘clientele’ with whom to interact and to invite to the final presentation of their project. This has been quite successful in tying their technical concepts to the realities of client needs.

6. CONCLUSIONS

Sustainable development requires understanding the relationship between technical aspects of energy production use and the human aspects of value energy is providing to people. This is at once an intellectual challenge and a pedagogical opportunity. Understanding the dynamics of energy's role on quality-of-life brings together technical, social, and humanistic thinking. Engineering students must engage with remote disciplines, while non-technical students can find an entrée into dialogue on technical matters. Both sets of students can benefit tremendously.

We propose that working across disciplinary boundaries to solve critical, real-world problems facilitates multidisciplinary studies. The context of the problem answers the age-old question of many technical students regarding their social science and humanities studies, "why do I need this?" At the same time, it exposes the non-technical students to technical matters in a context that reinforces the meaning of the science and the numbers. The students can see their efforts blending to address important problems. The teamwork tends to create a genuine interest in understanding each other's expertise. When Ebenhack created a cross-listed course with a colleague from anthropology in which they formed student teams of engineering and anthropology students to study options for more sustainable transportation systems, one of the delightful outcomes was expressed interest from several students to take more courses in the other discipline. Another excellent outcome was the successful development of deeper understandings of complex issues, by bringing together the perspectives of disparate disciplines.

There are gaps between technology and its use to serve human needs. Thus we believe that a new field of richly cross disciplinary research and education is emerging. Humanistic and social science studies, standing alone, will be no more robust than engineering or scientific studies standing apart from the social context. The compelling reality is that we must find new, innovative ways to work together on sweeping problems, across our disciplinary boundaries. The questions of how society is to move to more sustainable energy systems is a worthy challenge to bring students and faculty together to develop new paradigms for inter-disicplinarity.

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3rd International Symposium for Engineering Education, 2010, University College Cork, Ireland

METHOD OF TEACHING FLUID MECHANICS IN SOME SOUTH AFRICAN UNIVERSITIES AND ITS IMPLICATIONS FOR LEARNING

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Abstract

This study investigates the current method of teaching fluid mechanics and its implications for learning in undergraduate mechanical engineering classes in some South African universities. Open-ended questionnaires and classroom observation were used to gather qualitative data from both students and lecturers in this field. The results revealed that fluid mechanics is taught in a traditional form using Microsoft PowerPoint slides, textbooks and blackboards. It also emerged that this method of teaching presented learning difficulties for learners in some aspects of the fluid mechanics module. This study serves as a springboard for a more extensive study which measures the effect of introducing computer-animated instruction into the teaching of fluid mechanics in South African universities.

Key words: symposium, engineering education, undergraduate, fluid mechanics, teaching approach, mechanical engineering

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1. INTRODUCTION

In recent years there has been a shortage of qualified engineering experts (French, Immerkus & Oakes, 2005). Enrolment figures for engineering courses have dropped, while at the same time, the market demand for engineers is increasing (National Science Foundation (NSF), 2004; Li, McCoAch, Swaminathan & Tang, 2008). While enrolment for engineering courses in South African universities is very low, significant numbers of students also drop out or change course (French et al., 2005). In addition, larger percentages of students today are weak in mathematics (Felder & Brent, 2005). However, aspects of mathematics concepts form the fundamental conceptual framework in most of the engineering courses. Hence many engineering students find engineering modules too demanding because of their weak background in mathematics.

The motivation for this study emanated from awareness of the acute shortage of skilled workers in South Africa, particularly in the field of engineering. A considerable number of professionals, including engineers, have been leaving South Africa in search of greener pastures. Furthermore, the post-apartheid government inherited a crop of primary and secondary school science and mathematics teachers, the majority of whom do not have a strong knowledge base in their discipline (Naidoo & Lewin, 1998). Even fifteen years after the demise of apartheid, government efforts to provide schools with competent science and mathematics teachers have not been fruitful. The learning of science and mathematics in schools has been problematic and the yearly pass rate has been declining.

The government has mounted a campaign to encourage learners to study science and mathematics at high schools so that they can proceed to university to study engineering and other science courses that play a significant role in the socioeconomic advancement of South African society at large. Financial aid schemes have been set up by the government to support this. To this end, the Joint Initiative for Priority Skills Acquisition (Jipsa) declared an intention to produce 2500 engineers a year as a national output priority for South Africa (Apple, 2008).

A number of researchers have investigated the issues relating to low enrolment and graduation figures in the engineering fields in South African universities. Reed and Case (2003) investigated the factors that influenced learners to follow a career in engineering with a view to promoting a higher rate of enrolment and graduation from engineering studies at South African universities. The duo suggested that focused interventions around the factors that influence learners to follow a career in engineering can serve to encourage more learners into engineering fields. The results of their study were similar to the findings of Jawitz and Case (1998). The study by Li et al. (2008) pursued the same objective of attracting more learners into the fields of engineering in the United States of America by using an attitude measuring instrument to help engineering educators understand why many students stay away from engineering. Taraban et al. (2007a) studied the problem from the angle of engineering students' learning and conceptual understanding, revealing a disconnection between students' conceptual and procedural knowledge that was likely to block the development of deeper understanding. Taraban et al. (2007b) suggested that to draw more students to engineering practice, an innovative assessment capable of telling engineering educators more about students' problems with engineering concepts is imperative.

Ramsden (1992) notes that the approach to teaching is an important component of teaching that influences students' performance at university level and that a good teaching approach is likely to improve students' performance. This is why the problem of skills shortages in engineering in South Africa was approached from the angle of 'how the engineering modules are being taught'. The concern is to look into the current method of teaching engineering modules in South African universities with a view to introducing computer-animated aided instruction into the teaching method to facilitate teaching and learning. This view is in line with recent study on teaching (Nirmalakhandan, Ricketts, McShannon & Barrett, 2007).

Pre-study consultations with some of the lecturers in the field of engineering in South African universities revealed that fluid mechanics is one of the modules most engineering students find difficult to master, even though it is one of the principal modules in some of the engineering courses. Hence, this study focuses on the teaching of fluid mechanics at South African universities.

The traditional teaching of fluid mechanics concepts makes the module too abstract, dry and uninteresting. Timothy and Richard (2006) maintain that the traditional classroom instruction, whereby instructors illustrate engineering concepts with textbooks and blackboards as aids, is inappropriate. These media of instruction present the components of these objects in two-dimensions, whereas the concepts of mechanics are, in reality, three-dimensional. The result is that these students find the two-dimensional presentation confusing, they find it difficult to visualise what the lecturer is trying to explain.

2. PURPOSE OF THE STUDY

As noted, efforts are needed to promote engineering studies and to increase the qualifying rate of engineering students. Interventions are needed to retain students' interest and improve their understanding of key concepts, especially where fluid mechanics is concerned. The present study investigates the current method of teaching fluid mechanics and how it impacts on learning. The results are intended to serve as a springboard from which to proceed with deliberation and with a view to introducing computer-animated aided instruction (CAI) into the teaching and learning of fluid mechanics in mechanical engineering classes.

The following research questions were addressed:

(1) How is fluid mechanics taught to mechanical engineering students in South African universities that offer engineering courses?

(2) Do students experience conceptual learning difficulties in the field as a result of the way fluid mechanics is taught?

3. METHODOLOGY

3.1Research design

The choice of a research design to follow is based on the nature of the study, as well as the research question (Pirie, 1997). In this study, there is a need to examine the feelings and thoughts of participants about the way fluid mechanics is taught. Therefore, the study follows an ethnographic approach, which evolved from an interest in discovering how fluid mechanics is being taught in a normal classroom setting (in the normal teaching environment) in each of the participating universities. Therefore, survey and classroom observation methods were used to collect data from both students and instructors of fluid mechanics. Triangulation was used to avail ourselves of coherent, detailed and precise data.

3.2 Instrumentation

Questionnaire and observation checklist were the instruments used to collect the required data.

3.2.1 Questionnaire

The survey instrument was an open–ended questionnaire that had to be developed by the researchers, since the literature search failed to turn up an appropriate instrument that could be adapted to answer the research question. Validity and reliability checks were performed on the instrument.

Content validity-rating forms were given to 10 judges drawn from the fields of education and science education to validate the instrument. The judges were to report on the "sureness" and "relevance" of each item. There were three "sureness" levels with 1 = not very sure; 2 = pretty sure; 3 = very sure. And there were three relevance levels: 1 = low/not relevant; 2 = somewhat relevant; 3 = very relevant. Analysing the responses from the judges, items with a sureness mean ≥ 2 (this implies the judges were, at least, pretty sure about the item) and a relevance mean $\geq 66\%$ (this being interpreted as, most of the judges rated the item as somewhat or very relevant to what it is intended to measure) were retained. In addition, three of the judges that were used to validate the instrument were also used in the reliability check process. An internal consistency reliability check that was carried out gave a reliability coefficient of 0.76.

Similar questions (seven items) were presented to students and lecturers as separate questionnaires. The questions were couched to determine how fluid mechanics is taught and learned. The objective of effectively using two questionnaires (one for students and another for lecturers) was to collect convergence data.

Items 1 and 2 in the lecturers' instrument are meant to ascertain the number of students enrolled compared to the actual class attendance. The deficit accounts for the dropout rate. Some students might have dropped out if they could not cope in fluid mechanics classes. Items 3 and 4 were intended to solicit data on how fluid mechanics is taught, while the objective of items 5 to 7 was to gauge the effectiveness of the teaching method. The questions include: *In your own view, which topic in fluid mechanics do students normally find difficult? How would you describe students' perception of fluid mechanics as a module in a mechanical engineering course?*

Item 1 of the students' questionnaire was intended to determine the gender of the participants. Items 2 and 3 were intended to gauge the effect on learning of the method used in teaching fluid mechanics. The questions include: *Which topic/s do you find most challenging in fluid mechanics*? (item 2); *Do you find fluid mechanics classes too theoretical and uninteresting*? (item 3). Questions to ascertain how fluid mechanics is taught include the following: *Please describe how your fluid mechanics lectures are normally conducted* (item 4)*; please describe how a typical tutorial session referred to in 6 is normally conducted* (item 7).

A member of staff of the University of South Africa who specialises in data analysis and questionnaire development was requested to undertake a peer review of the instrument, which was also piloted with the help of first-year thermodynamics students and their lecturer at one of the universities within the country. The students and lecturer who participated in the pilot study were not involved in the main study. The few changes resulting from the pilot study were made to items that were considered potentially confusing, and that might therefore not yield the required information.

The lecturers' and students' questionnaires were sent to study participants by email to give them enough time to patiently complete it. In some instances, the researcher administered the questionnaires directly to participants during classroom observation. Only six of the eight participating universities returned responses. This represented 75% return rate.

3.2.2 Classroom observation

Classroom observation was meant to corroborate the data gleaned from the questionnaire items. An observation checklist was prepared to collect data during the classroom visit. The checklist format contained the events and behaviour to be observed and how this information is to be recorded. The instrument content covers the teaching approach used by the lecturer; the lecturer's review of previous work; student population; classroom space; furniture (including modern classroom electronic equipment used as aids); how a new topic was introduced; guided practice; and students' independent practice.

The checklist contents need to meet the objectives for which the instrument is constructed to be able to measure what it supposes to measure. Hence, the instrument was face-validated by an expert in the field of education; this exercise resulted in reconstruction of some parts of the contents. Again, an internal consistency reliability check on the instrument yielded 0.68.

Two rounds of scheduled classroom observations were conducted in each of the eight institutions. During the classroom observation relevant events were recorded using the observation checklist and in some instances notes were taken.

4. DATA ANALYSIS

4.1 Analysis of the questionnaire responses

We analysed responses to the questionnaire by classifying the survey items and identifying the coding units that answered the research questions. The responses were coded by specialists to provide an independent view of the data analysis.

The collected data were organised and a spreadsheet was created. The coding categories were formed as follows: 1 for traditional approach; 2 for traditional approach aided by Microsoft PowerPoint; 3 for student-centred approach aided by animation software; and 4 for other teaching methods. After this, data were sorted into different categories. This procedure enables us to identify the themes evolving from the survey. Like Mapolelo (2003) and Malone (1996), we compared all the evolved themes within each of the participating institutions (lecturers' responses were compared with students' responses and students' responses with each other), noting similarities and differences, after which we drew up an inter-institutional comparison.

4 .2 Analysis of data gained from classroom observation

Data from the observation checklist were gathered and organised, as we review all field notes and create a spreadsheet. The analysis includes an in-depth look at the method used by the participating lecturers to teach fluid mechanics and what the students were experiencing in building foundational knowledge. The data were put into spreadsheet format and grouped according to the research questions. For example, students' applying critical thinking skills as the lecture proceed by asking and answering questions, ease of building foundational knowledge, and students sharing knowledge with classmates as the lecture progresses.

5. RESULTS

Six out of eight universities returned their survey responses but classroom observations were done in all the eight universities. Though we analysed all the data but our result were based on the six universities from which we got complete data.

The analysis of the questionnaire data showed that an average of five students per university stopped attending fluid mechanics classes a few weeks into the lectures. We could not interview this set of students to find out exactly why they dropped out: perhaps they find fluid mechanics difficult.

Both questionnaire and classroom observation data on the teaching method used revealed that the teaching of fluid mechanics conforms to the traditional approach in all the universities that participated in the study: in four of the universities, lecturers taught with the aid of PowerPoint presentation and data projection, but without interactive animation. In one other institution the chalkboard and overhead projector were used as basic teaching aids: the overhead projector was used to display diagrams prepared on transparencies. In another participating institution, only a chalkboard was used. Data from the observed items revealed an average student population of 82, and most of the classrooms were spacious and reasonably furnished with equipment that facilitates teaching (like computers and electronic communication peripherals).

The results from the classroom observation were also indicative that during lecture and guided practice at the tutorial sessions, students struggled to understand the basic fluid mechanics concepts, and there was not much interaction between the students and lecturers in the class. Students were always quiet throughout a lecturer period and hardly answered the lecturers' questions correctly. The lecturers had to go over these concepts repeatedly, even those ones that were taught previously which were relevant to the present topics. It also emerged from the survey results that students find some aspects of fluid mechanics difficult.

An example of one of the lectures observed is given here which was on control volume. In this lesson the lecturer started by explaining the resolution of a problem relating to control volume. The problem was about a plate set up parallel to a flowing stream. After displaying the PowerPoint slide on which the problem was written, he went on to start solving the problem on the chalkboard without any student engagement as follows:
"Given a plate which was set up parallel to a flow, the stream is a river or a free stream of uniform velocity $\mathbf{V} = U_o i$". He went on to explain: "Pressure is assumed to be uniform, the no-slip condition at the wall of the plates brings the fluid particles there to a halt." Here the lecturer paused for about five seconds to read through a note which he had in his hand. He then went on to relate that "the slowly moving particles retard their neighbours above them so that at the end of the plate there is a significant retarded shear layer, or boundary layer of thickness $y = \delta$ ". He then moved to the other half of the board and started writing "the viscous stream along the wall can sum to a finite drag force on the plate". As he was explaining and writing on the board, he pointed to the diagram he had on a PowerPoint screen. He then told the students "to make an integral analysis and find the drag force D in terms of the flow properties ρ, U_o,, δ and the plate dimension L and b". He later solved the problem on the chalkboard and gave a related problem to students to solve as homework. The lesson was completed in 40 minutes.

6. DISCUSSION

The results of the study under review showed that the lecturers adopted a traditional approach to the teaching of fluid mechanics at South African universities that offer BEng degree programmes. This method of teaching fluid mechanics in the participating universities impacted negatively on learners' conceptual understanding of the principles of fluid mechanics.

Effective learning of the mechanics of fluid flow cannot take place with the exclusive aid of textbooks and chalkboards or even of non-interactive PowerPoint displays. It emerged from the results that study participants were struggling to understand what they were taught: they were always quiet, looked passive and hardly answered questions correctly in the class. These media of instruction leave too much to students' imagination and may lead to alternative conceptions. Fluid flow is a physical, three-dimensional phenomenon, which could be the reason why students found its abstract presentation difficult to grasp. This may be one of the reasons why some students dropped out of the fluid mechanics class a few weeks into the lectures.

In addition, the study participants also find fluid mechanics classes dry and uninteresting. In engineering lecture classes, there is supposed to be interaction between the lecturers and the students, and among the students, as they share knowledge and skills. This will encourage the students to work together and discuss concepts and ideas among themselves.

These study participants are studying to become practising mechanical engineers at the end of their training; they should be able to apply theoretical concepts to solving real-life practical problems. Georghiades (2000) describes knowledge transfer as the ability to apply new concepts and skills in multiple contexts. Hence, for learners to be able to apply the theoretical concepts gained in the class in real-life contexts, deeper understanding of the knowledge base is imperative.

7. CONCLUSIONS

Traditional lecturing to a passive audience creates a passive learning environment. However, engineering students learn better by participating, acting, reacting and reflecting (Nirmalakhandan et al., 2007). The researchers believe that such a learning environment can be achieved in a classroom where teaching is supported by computer-animated instructional aid (Shannon, 1994 in Marek, 2005). Such a teaching aid will help the lecturers to present fluid mechanics concepts in their original three-dimensional forms. It will also facilitate illustration of these concepts that would have otherwise presented a significant barrier to their students' understanding of fluid mechanics. Further research is needed to ascertain the impact of computer-based animated instruction in fluid mechanics classrooms.

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Integrating Environmental & Social Considerations in the Curriculum of Undergraduate Electronic & Computer Engineering Students

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Abstract: This paper discusses the role that the Engineers Ireland accreditation process had in helping to embed two problem based learning (PBL) modules in the Department of Electronic & Computer Engineering at the University of Limerick which viewed together aim to give a rounded perspective on sustainability as it might apply to graduates in these disciplines.

The first of these is a second year module entitled "The Engineer as a Professional" dealing largely with engineering ethics and the evolution of codes of ethics, the role of the engineer in society and engineering responsibility. This module is examined using continuous assessment and is divided into ten problems or case studies that the students must solve in groups of three or four and make presentations to the class on the outcomes of their work. The assessment also requires the students to keep a reflective blog. Through problem solving the students are challenged to examine their own perceptions of an engineer's role and the social impacts of engineering, while giving them a basic foundation in ethical theory and an overview of the competences of professional engineers as outlined by Engineers Ireland.

The second of the modules is a fourth year module entitled "Electronics & the Environment". Again, this module is examined using continuous assessment, comprised of approximately ten problems, worked on in groups of three or four. The presentations and blog are also required. The problems cover topics on sustainable development, life cycle thinking, life cycle assessment, streamlined life cycle assessment, and other problems and design case studies in the electronics and information and communication technology (ICT) area.

Keywords; accreditation, problem based learning, engineering education, engineering ethics, technology and sustainability.

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1. THE CHANGING RESPONSIBILITIES OF ENGINEERS

The role afforded to engineers by society has changed dramatically in the last century. Almost 100 years ago, the 1912 Code of Principles of Professional Conduct of the American Institute of Electrical Engineers stated "The Engineer should consider the protection of a client's or employer's interests his first professional obligation and therefore should avoid every act contrary to this duty" (Harris et al., 2005). This is in stark contrast to the situation today where this obligation has been turned on its head. Engineers are now told that they should "place responsibility for the welfare, health and safety of the community at all times before responsibility to the profession, to sectional interests, or to other engineers" if they wish to be considered for the title of Chartered Engineer (Engineers Ireland, 2005). When making a commitment to comply with the current Code of Ethics from Engineers Ireland, engineers are undertaking to "promote the principles and practices of sustainable development and the needs of present and future generations" and to "strive to ensure that engineering projects for which they are responsible will, as far as is practicable, have minimal adverse effects on the environment, on the health and safety of the public and on social and cultural structures" (Engineers Ireland, 2009). These statements, and others of similar sentiment, are now liberally spread throughout these touchstone documents. The language is very clear; sustainability is now considered to be a core concern for engineers and must be given due priority in the formative education of engineers.

2. THE ROLE OF ACCREDITATION IN EFFECTING CHANGE IN ENGINEERING COURSES

2.1 Accreditation

Engineers Ireland has as one of its purposes "setting up and maintaining proper standards of professional and general education and training for admission to membership or to any category of membership of the institution" (Engineers Ireland, 2007). Programmes which satisfy their criteria are deemed to meet the education standard required of individuals seeking one of the registered professional titles of Chartered Engineer, Associate Engineer and Engineering Technician. Moreover, under international agreements such as the Washington, Sydney and Dublin Accords, accreditation decisions of Engineers Ireland are accepted in signatory countries on the same basis as their "home" graduates. Engineers Ireland is also a member of the European Federation of National Engineering Associations (FEANI) and all engineering degree programmes that they accredit as satisfying the educational standard for Chartered Engineer are accepted in the member countries of FEANI.

This domestic and international recognition of the high education standard that a programme must achieve to receive such accreditation is rightly coveted by engineering departments in institutions throughout the country and those who have achieved accreditation in the past are loath to lose it. It is the view of the author that the accreditation process undertaken by Engineers Ireland every five years can become the primary lever in effecting change, or even transformation, to more sustainable paradigms in engineering education. From section 1 it is clear that the accreditation panels are mandated to adopt such an approach and if pursued constructively, yet aggressively, are best positioned to overcome inertia, conservatism or lethargy that may exist in engineering departments.

2.2 Experiences of Accreditation

The electronics course was one of the original courses at the National Institute for Higher Education (NIHE) Limerick, starting with a B.Tech in 1972 before moving to a BSc. in the late seventies and a B.Eng in the early eighties. The B.Eng. course first achieved Institute of Engineers Ireland (IEI) accreditation in 1985 and has maintained continuous accreditation ever since. The course is now designated as a B.E. In the report from the 2005 Engineers Ireland accreditation visit it recommended that

> *"Ethical, environmental and such matters should be strengthened within the core modules of the programme".*

In response to this the department developed a core module entitled "The Engineer as a Professional" dealing largely with engineering ethics and the evolution of codes of ethics, the role of the engineer in society and engineering responsibility. This module was included as core in the autumn semester of second year in the engineering programmes, replacing a choice of some general non-engineering elective modules. The department also introduced a module entitled "Electronics & the Environment" which was included as a specialist elective in the autumn semester of fourth year. This module covers topics on sustainable development, life cycle thinking, life cycle assessment, streamlined life cycle assessment, and other problems and design case studies in the electronics and ICT area. However, it was not given core status as agreement could not be reached on what module it would replace. The conversations at this time were fractious and arguments revolved around the issue of the relative importance of this topic vis à vis more traditional technical subjects. In the view of the author this sentiment reflects the emotional investment that many academics have made in their own particular specialist area and represents a significant barrier to change.

In the subsequent accreditation visit in December 2009 the report includes a section on features and strengths of the programme which states

> *"The Panel were impressed by the evidence for academic achievement on the programme in several areas. The core "Engineer as a Professional" module was felt by the Panel to be an excellent addition to the programme since the last accreditation panel visit, and its teamwork development activity in particular was felt to be a model of good practice that could be promulgated as such within the sector.*
>
> *The Electronics & the Environment module was also noted as a very positive addition to the programme, although not contributing to the Programme Outcomes for every student on the programme because of its position as an elective module."*

The Electronics & the Environment module is now included as a core module in the Electronic Engineering degree. This is in spite of the fact that achieving European Credit Transfer and Accumulation System (ECTS) compliance involved a significant restructuring of the programme to achieve uniformity with the rest of the University of Limerick's (UL) programmes.

3. PROBLEM BASED LEARNING

The traditional University teaching model in science and engineering is teacher centered and based on lecture, tutorial and laboratory sessions. This can encourage reliance on lecture/laboratory material for the answers necessary to complete coursework and pass exams but does not necessarily encourage a deep and lasting understanding of the subject, nor help students to apply their knowledge in a practical situation. While this problem applies to all areas it is particularly worrisome in modules dealing with sustainability in engineering due to its role as a guiding myth as opposed to an objective set of design criteria (Allenby, 2007) so when inserting these new modules in to the program it seemed sensible to attempt to avoid these problems. In conjunction with this the PBL methodology fits very well with the millennial generation students expectations of personalisation and customisation of experiences. It can facilitate their desire to explore and experiment, to get involved, and test and, very importantly, to receive instant gratification (Ranky 2010). A set of carefully designed problems using the PBL methodology can be used to overcome these pitfalls and achieve the desired learning outcomes.

PBL is now used across the world in a wide range of disciplines. It is a shift from the teaching paradigm to the learning paradigm. The focus is on what students are learning rather than what the teacher is teaching. At the core of PBL curriculum design is a set of well-designed, ill-structured or open-ended, real-life, engaging problems. Research shows that compared to traditional lecture based instruction PBL, improves student understanding and retention of ideas, critical thinking, communication and problem-solving skills, as well as student’s ability to adapt their learning to new situations. During the PBL sessions the instructor effectively acts as a consultant, guiding the students as they search for the appropriate resources and providing scaffolds for learning (Barrett et al., 2005).

Both “The Engineer as a Professional” and “Electronics & the Environment” are examined using continuous assessment and PBL. The modules are divided roughly into ten problems, each of one week in duration that the students must solve in groups of three or four. Each group has a chair, a scribe and a timekeeper and they are presented with the problem at the start of the first session of the week. The lecturer generally gives a 30 minute background lecture and engages in questions and answers with the students. During this session they must

- Name facts
- Clarify what they think the problem is
- Brainstorm ideas based on prior knowledge
- Identify what they do not know (learning issues)
- Specify an action plan and assign tasks

After this session they engage in independent study on the learning issues identified. When they return for the second session of the week they share information and resources, and peer-teach their proposed solution to the problem.

In the final session of the week a representative of each group makes a presentation to the class on their solution to the problem and the lecturer gives an overview of the topic and feedback on the presentations. The students also have an opportunity to ask questions and discuss the topic. After this they write-up an individual reflective blog on the problem and this is submitted the following week.

4. THE ENGINEER AS A PROFESSIONAL

The learning outcomes for "The Engineer as a Professional" are as follows

- The students will analyse and discuss the utilitarian and respect for persons ethical principles.
- The students will examine and discuss the relationship between common morality and professional codes of ethics
- The students will demonstrate an understanding of the role of reflective practice in continuous professional development
- The students will demonstrate an understanding of the role and responsibilities of professionals in society and the function of professional bodies.
- The student will analyse the importance of teamwork and the role of leadership in the completion of complex tasks.
- The students will demonstrate their capability of making a competent technical presentation to their peers.
- The students will demonstrate their ability to work in teams through practical activities.
- The students will demonstrate their written communication ability through a series of technical reviews and reflective logs.
- The students will demonstrate their ability to critically analyse their own learning requirements through a series of reflective logs.
- The students will demonstrate their ability to analyse problems from an ethical viewpoint and develop creative middle ways in cases of conflicting values.

Through the course of the semester the weekly projects seek to achieve one or more of these learning outcomes. Some of these projects involve undertaking a structured reflection, supported by recommended literature, based on an activity or exercise undertaken by the class. For example, the class spends a half day on teamwork exercises at the UL Activity Centre, shown in Figure 1, after which they must consider the role of teamwork in engineering and reflect on their performance in teams from individual, relational, contextual and development perspectives.

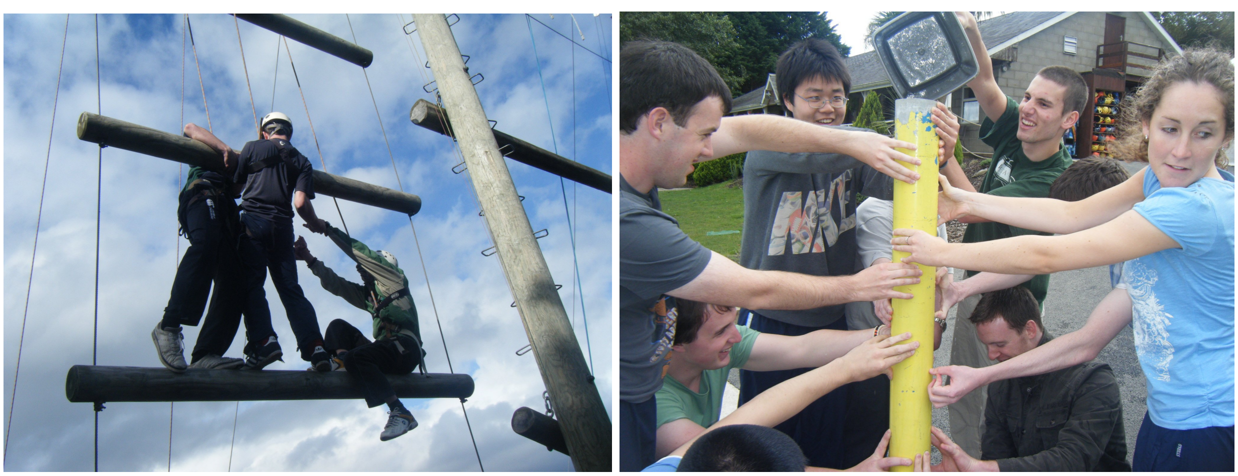

Figure 1 Engineering students participating in team activities at UL Activity Centre

Another exercise like this is to give the students a class session to examine the "Carter Racing Case Study" which is based loosely on the events leading up to the Challenger disaster in 1986. After making a decision on whether to race (launch) or not the students must reflect on their decision giving particular attention to the issue of responsibility in engineering with reference to professional bodies and codes of ethics. The story of Roger Boisjoly in the Challenger case makes for a particularly inspirational engineering role model (Harris et al., 2005).

The problems also take the form of case studies where students must delve into the relevant literature in order to piece together a coherent solution. An example of this is where they must use the line drawing methodology to make a decision on a course of action when given a case study that presents an ethical grey area. In order to do this of course they must first research the methodology, examine some previous case studies that have applied it and then set about applying it themselves. Examples of case studies would include situations where gifts/bribes or invasion of privacy are involved but not clear cut.

Another very effective problem which helps students to explore different ethical theories is to have groups prepare arguments for a debate on the use of human cadavers as automotive crash test dummies ("utilitarianism" says yes, "respect for persons" says no). After this debate they must then explore creative middle ways.

5. ELECTRONICS & THE ENVIRONMENT

The learning outcomes for "Electronics & the Environment" are as follows

- The students will analyse and discuss the inter-relationship of economic, social and environmental aspects of sustainable development
- The students will demonstrate an understanding of the importance of examining the whole life cycle when evaluating environmental impacts and evaluate the various methodologies for so doing.
- The students will examine and discuss the relative environmental impacts of different technologies and different methods of delivery of function.
- The students will examine and discuss the relative merits of different eco-labelling schemes.
- The students will create designs of sustainable technological systems.

Again, through the course of the semester the weekly projects seek to achieve one or more of these learning outcomes. The early weeks in the semester are used to establish basics such as what is sustainable development, life cycle impacts and life cycle assessment (LCA). The problems advance to interpreting reports such as Ericsson's LCA study on a 3G system and suggesting improvements in system design based on the results. The problems progress to comparative LCAs between thin client and thick client computing or LED and fluorescent backlight monitors. The PBL methodology also enables classes on topical subjects and the release of Windows 7 presented the opportunity to examine whether this new operating system would be beneficial to the environment or not. Further problems explore PC eco labels and eco design, product service systems and the Waste Electrical & Electronic Equipment (WEEE), Restriction of Hazardous Substances (RoHS) & Energy Using Products (EuP) Directives. The final capstone project requires the students to design a sustainable computing service as part of the Limerick Regeneration project.

6. CONCLUSION

This paper has described the experience of the Dept of Electronic & Computer Engineering at the University of Limerick in its attempts to include sustainability in the curriculum of its undergraduate degrees. Using the Engineers Ireland accreditation process as a catalyst for change it has introduced two new modules focussing on the ethical responsibilities of engineers towards society and the environment. Given the enormous scope of these issues and the pressure for space in the typical undergraduate engineering programme the PBL methodology has been found to be a very effective way of introducing the subjects and stimulating independent research by the students. It also satisfies the demands of millennial generation students for personalisation and customisation of experiences; to explore and experiment, to get involved and test and to receive instant gratification.

In the view of the author, the use of individual modules to address these areas should be seen as a stepping stone to introducing sustainability throughout the whole curriculum. However, the use of dedicated modules is vital to developing, in our students, a sound fundamental and theoretical understanding of sustainability upon which they can build on in their technical subjects and should not be bypassed. The application of theoretical principles to the analysis and solution of engineering problems is the essence of engineering practice and no less of a theoretical foundation should be afforded to the sustainability dimension of this practice. The inclusion of small aspects of sustainability into individual modules in the absence of a detailed introduction and overview runs the risk of simplifying the issue into "rules of thumb" or simple checklists which run counter to best educational practice. A deeper theoretical engagement gives students the tools to build their understanding of sustainability throughout their careers which is essential for lifelong learning and continuous professional development.

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TEACHING ETHICS TO ENGINEERS – REFLECTIONS ON AN INTERDISCIPLINARY APPROACH

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Abstract: This paper outlines an interdisciplinary approach to teaching Ethics to undergraduate Engineering students at Queen's University Belfast. Focusing on the Royal Academy of Engineering's 'Statement of Ethical Principles' we outline how from two different disciplinary perspectives (politics/philosophy and Engineering), over two years and with two cohorts of undergraduate Engineering students, we approached the teaching of Ethics to Engineers. Through the evaluation of student learning and staff reflection on the approach, we demonstrate the need for flexibility and adaptability in a) teaching Ethics to Engineers within a context where it is not often seen as 'central' or a 'core' competency and especially b) in relation to interdisciplinary approaches to teaching Ethics to Engineers.

Keywords; Ethics for Engineers. Royal Academy of Engineering's Statement of Ethical Principles, interdisciplinary teaching, Engineering education, Engineering and Sustainability.

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1. BACKGROUND /MOTIVATION

The teaching of Engineering Ethics at Queen's University Belfast (QUB) to Civil Engineering students, who have mostly passed through the Northern Irish School System, poses a number of problems for educators. Perhaps most prominent among these is the students' reluctance to engage in what is perceived as 'soft' (non-numerical) subject matter, where answers are rarely clear cut. This contrasts with the students' experience during the later part of their secondary education. Following completion of GCSE exams, students specialise in three to four technical subjects with a strong practical perspective and a significant numerical basis, where single correct answers are routinely encountered in the problems they confront; this continues into the first years of their university education. This is at odds with situations often confronting practicing Civil Engineers who are expected to make appropriate decisions based on largely qualitative information.

The problem with teaching Engineering Ethics is further compounded by an absence of expertise among academic staff, or reluctance of Engineering academics to specialise in the subject. Conversely, those routinely specialising in the study of Ethics rarely have the technical background to present topics in a format that may appear relevant to stimulate the interest of Engineering students. The requirement to address Engineering Ethics in degree courses in Civil Engineering as part of the accreditation process and the need to demonstrate the relevance of Ethics to Civil Engineers in their day-to-day activities has led staff at QUB to adopt a cross-disciplinary approach to teaching the subject to a class of 100+ Level II (second year) Civil Engineering Students. Prior to developing the aspect of the curriculum dealing with Engineering Ethics, preliminary discussion with final year undergraduate students suggested that many were unaware of the relevance and importance of Ethics in professional practice, despite being implicitly exposed to related issues, particularly in the latter part of their university education. Inquiries concerning student understanding of Ethics as a subject ranged from an approach for dealing with personal matters of conscience to an academic pursuit with little value in helping a professional to meet the needs of society. These findings suggested the need for a more explicit acknowledgement of the importance of Ethics within the Civil Engineering course curriculum.

2. PEDAGOGICAL AIMS

More explicit incorporation of Ethics in a Civil Engineering curriculum aimed to demonstrate the need and utility of an ethical code in professional practice in addressing dilemmas professionally, while meeting the greater needs of society. More specifically, the introduction of the topic aimed to demonstrate how current ethical guidelines are sufficiently flexible to "respond to moral exigencies and demands for efficiency and professional effectiveness" (Lozano, 2006)

While of course one can take (and is often tempted to take) a 'tick box' approach to the teaching of ethical issues within the Engineering curriculum, the key to the approach we took was to emphasise the importance of students having 'learnt', understood, and internalised the centrality and importance of ethical considerations in the professional practice of Engineering in general and, more specifically, the four fundamental principles outlined in the Royal Academy of Engineering's (RAE) 'Statement of Ethical Principles' (SEP) , namely:

- Accuracy and Rigour
- Respect for Life, Law and the Public Good
- Honesty and Integrity
- Responsible Leadership: Listening and Informing

(Royal Academy of Engineering, 2007)

We employed the RAE Engineering Ethics Curriculum Map as a basis for achieving these goals (Royal Academy of Engineering, 2008), with emphasis on developing a strong understanding of fundamental issues, obligations and responsibilities that require an Engineer to act ethically. Overall, presentation of subject matter focused on conveying the relevance of microethical issues, focusing on the individual and internal relations within the Civil Engineering profession (Herkert, 2005), before introducing macroethical topics and their importance to wider social context.

3. APPROACH

This paper offers an analysis and discussion from the 'input' or delivery aspect of the teaching of Ethics to undergraduate Engineers, focusing on discussion of the motivation, views and expectations we had as teachers. We explain how we approached the teaching process over two years and how the 'output' side (student feedback and our evaluation of how successfully intended learning outcomes had been achieved) influenced the modifications we made to course content during the latter part of this period.

The Royal Academy of Engineering's *Engineering Ethics Curriculum Map* states that "The study of Ethics helps students to develop widely applicable skills in communication, reasoning and reflection. These skills enhance students' abilities and help them engage with other aspects of the Engineering programme such as group work and work placements" (Royal Academy of Engineering, 2008). In this way the RAE makes it clear that the teaching of Ethics ought not be seen as a 'bolt on' or 'tick box' exercise that has to be gone through in order to get to the 'real' or 'core' skills, training and experience that constitute Engineering. In approaching the design, delivery, assessment and evaluation of teaching Ethics to Engineers, we explicitly sought to build in not simply the students' exposure to ethical issues and the RAE Statement of Ethical Principles, but to encourage them to recognise the need, in accordance with the spirit of the RAE curriculum map, the benefits of understanding and internalising ethical considerations as professional Engineers, and the responsibilities attendant upon being a member of the Engineering *profession*; this included standards, codes of conduct and behaviour to which they must adhere. Moreover, we aimed to demonstrate that the approach not only had implications at the personal, company and community level, but also contributed to the well being of society in general.

From a teaching perspective, simply obliging or requiring students to listen passively and discuss ethical issues was a necessary but not sufficient condition for the type of learning we wanted them to experience. Indeed the use of alternative methods to this approach has been acknowledged as a superior means of improving student learning and understanding in third level education (Race, 2001). While mindful of the limited time and resources allotted to this section of the curriculum, our approach was informed by our view of students. We viewed students as active learners and, following a review of case studies (e.g. Stern & Pimmel, 2002; Prince, 2006), endeavoured to apply a subset of the educational techniques recommended in the RAE Engineering Ethics curriculum map, which we considered most appropriate to the students' background and physical constraints on teaching (class size, location, time allocation).

In view of the considerable logistical and pedagogical problems associated with the development of a separate module dealing with Engineering Ethics, for pragmatic reasons we elected to integrate an Ethics programme into an existing Communications module, where many related and relevant topics were already being presented, e.g. plagiarism/collusion, responsibility of Engineers in/for disasters. To ensure a more widespread appreciation of the relevance of Ethics, a broad range of teaching formats were incorporated into the programme, accounting for a range of learning styles. Previous anonymous student evaluations of the Communications module suggested that the class responded more favourably to active/interactive teaching techniques, as have been noted elsewhere (Stern & Pimmel 2002). Furthermore, Ethics-related course content was aligned with other activities within the Communications module to ensure that students could avail of the opportunity to integrate skills from other parts of their training, e.g. the use of graphics to help meet the principle of listening and informing.

4. PROGRAMME DETAILS

Initial course presentation involved an introduction to Ethics in the form of a lecture, which focused on the individual's responsibility for behaving and thinking ethically. Specifically in the lecture, (but also in subsequent group work,) the benefits of 'being ethical' (in the sense of this being a constitutive as opposed to a contingent aspect of the practice of being 'good' and 'professional' Engineer) were outlined. The topic was initially couched in terms of personal mores, which was then developed to demonstrate how these could be transferred to professional practice, e.g. the everyday respect for the life and dignity of members of the public must also be considered at a professional level. Critically, the lecture highlighted the point that not all issues in the Engineering profession are addressed by the law, and Engineers must often make value judgements that may have wider implications, but not necessarily be of legal significance; in this sense following appropriate ethical guidelines can have considerable long-term practical benefits. We underscored the argument made by Robinson (2005) that contrary to a widely held perception, working ethically has considerable practical benefits and increases employability. In the lecture we outlined 'practical benefits' as including:

- Not being sued
- Not being struck off
- Having a good reputation
- Not having to remember falsehoods
- Being able to sleep easy at night and not worrying…
- Permitting learning from mistakes more openly and honestly
- Taking pride in having high ethical and professional standards
- Helping resist temptation of taking short cuts.

While outlining the 'practical benefits' of being ethical could be constructed as appealing to more 'self-centred/self-interested' reasons for 'doing the right thing', we presented the view that:

a) these personal practical benefits were balanced against other aspects of teaching Ethics in which 'doing the right' thing was suggested to sometimes require the personal courage (especially in relation to being a junior member of a team within a strict hierarchical work management context) to challenge established cultures or decision-making processes and therefore potentially result in depriving the individual of short term benefit;

b) the inclusion of the above long term practical benefits were important to communicate the agency and action required to 'act ethically', that is, being ethical was not something that could safely remain as an internal ethical monologue, such that students would think that 'being ethical' was a matter of 'being aware' of the SEP for example, but not implementing and acting on them. In short, we were conscious of the need that students did not regard ethical issues as 'abstract', stand alone matters divorced from professional action. As indicated below, we feel that the first year we taught this element of the course the approach adopted added to, rather than challenged, this misperception.

c) ethical actions have benefits beyond those awarded to the individual or employer. Engineering decisions will impact on society and an Engineer's professional responsibility is ultimately to the general public.

In the rest of this paper we reflect on our experience of teaching Ethics to undergraduate Engineers. What follows needs to be qualified by the fact that we did not originally construe this teaching as a 'research project' and did not monitor or evaluate the student learning over the two years in a manner which would provide empirical data or enable us to definitively draw causal relations. However, based on our own observations of student learning, student assessments and our own evaluation of the teaching, what we provide in the rest of the paper are grounded judgements as to the design, delivery and student learning.

5 INTERDISCIPLINARY TEACHING

This paper is based both on our experience of teaching Ethics to undergraduate Civil Engineering students,. coming from two different disciplinary backgrounds (Engineering – Flynn and Politics/Philosophy – Barry), and also from other published research on interdisciplinary approaches to Engineering Ethics teaching (Graber and Pionke, 2007).

A criticism that could perhaps be levelled at the RAE and other professional Engineering bodies, e.g. Institution for Engineering and Technology, Engineers Ireland, and some existing research and publications on teaching Ethics to Engineers, is that not enough emphasis is placed on adopting an interdisciplinary approach, meaning bringing in colleagues from other disciplines to teach this aspect of the Engineering curriculum. The need for such an approach has also been highlighted elsewhere (Herkert, 2005). As well as sharing the load and exposing students to a different but related disciplinary approach to their subject (hence bringing some variety to the delivery of the curriculum) such interdisciplinary, cross-department teaching helps develop both teaching and research synergies and builds collaborative networks as well as interpersonal connections.

In the case study presented here, emphasis on 'Sustainability/sustainable development', one of the areas of specialism of one of the authors (Barry), given its intrinsic interdisciplinary character, was extremely useful as a focus through which to explore ethical aspects of Engineering issues and their wider impacts on the quality of life in society. While not exhausting the range of potential Engineering issues/case studies through which Engineering Ethics could be explored, there is much to be said in favour of focusing on topics which highlight the overlap between Sustainability and Engineering in terms of the contribution of Engineering to achieving sustainability across economic, social and environmental 'bottom lines' (Barry and Farrell, 2010).

A focus on Sustainability can provide an extremely useful 'bridge' to integrate and link the harder technical/material dimensions of Engineering and the softer human/social dimensions in a robust, coherent and easily understandable manner. Thus a focus on Sustainability and Engineering within the context of sustainable development, automatically moves teaching and research in an explicitly interdisciplinary manner in which it is hard not to engage with social and ethical aspects of Engineering. Moreover, unlike other aspects of the Social Sciences, all course participants will have been exposed to the topic in previous courses, albeit from a more technical perspective. Sustainability thus provides a useful frame of reference for relating the potential of Engineering decisions to impact on wider society.

6. MODULE PRESENTATION AND OUTCOMES

Year 1:
In the first year of teaching this section of the module, the lecture on 'Ethics for Engineers' was presented by Barry where generic philosophical concepts that underpin the study of Ethics were presented to students. This included utilitarian concepts (benefits for the greatest good), and Kantian concepts (relating actions to duty) and legalistic concepts (following established procedure). Subsequent facilitated workshops, where students were divided into small groups and asked to discuss / apply different ethical approaches to specific problems, aimed to both deepen student understanding of subject matter and provide the course instructors with formative feedback. Intended learning outcomes corresponded broadly to those suited to Level I and Level II on the RAE Engineering Ethics Curriculum Map, namely to be able to outline the general principles of the ethical framework in Engineering, including the Engineer's responsibility and to be able to identify ethical issues relating to Engineering situations through examples.

To achieve these outcomes all groups were given a hypothetical case study of an Engineering situation in class, which raised ethical issues. Participants were then invited to discuss each approach in their assigned groups, to show how the three ethical approaches were applicable, and how the SEP could be used to determine appropriate course/s of action. The approach adopted aimed to engage all class members. An open discussion between groups was initiated by the class facilitator by asking spokespersons from each group to present an issue using one of the three ethical concepts. Following the class, a summative assessment where students needed to source a case study, relating to a specific aspect of the Statement of Ethic Principles, aimed to consolidate student learning and provide a means by which participants could integrate their knowledge of Ethics with technical and communication skills in a final written report and oral presentation. To further facilitate participation the summative assessment marking scheme aimed to provide the opportunity to cross-examine presenting groups and for groups asking and responding to obtain further marks from a fixed pool of marks based on the quality of questioning and responses, i.e. one group could steal marks from another based on the quality and relevance of the dialogue

Outcome:
Student feedback during the workshops identified from an early stage that the students experienced considerable difficulty in relating the concepts presented in the lecture to the case study; this was in part reflected in their reluctance to engage with the instructor and the rest of the class. This finding was further corroborated by the nature of the student-selected case studies presented at the end of the module, where small groups reported on the relevance of particular principle from the SEP and its relevance to the case study, without viewing the problem in its wider context, i.e. in terms of responsibility to society.

An overall review of student performance in the small-group work and written submitted assignments demonstrated that, while some students had developed a basic understanding of the subject matter and had a grasp of the main issues, the teaching approach fell short in terms of deeper student learning. This dissatisfaction with the shallow level of student understanding and lack of appreciation of the applicability of ethical issues to Engineering practice appeared to be due in large part to the fact that the teaching strategy chosen i.e. using terms, concepts and approaches that were simply not part of the students previous learning experience. It led to a complete review and a decision to try a different strategy in the second year.

Year 2
Poor performance in achieving the module intended learning outcomes in Year 1 prompted an overhaul of module structure and presentation. Consultation between both instructors led to a consensus that abstract philosophical concepts should be more firmly related to concrete examples. A restructured introductory lecture focused more on the perspective that different parties in a hypothetical Engineering problem may have on the same issue, e.g. how would a problem be viewed

by a regulator, financier or client? Presentation of divisive topics in class provided a background for emphasising the contrasting views that individuals may take of appropriate action to be undertaken in tackling problems, including raising the issue of to whom the Engineer is ultimately accountable. This approach provided a basis for introducing the RAE SEP as a guideline by which Engineers should practice, and further underscoring to the class that the Civil Engineer's ultimate responsibility is to society. Following this approach prompted greater discussion and appeared to provide a more stimulating means of introducing the SEP.

Associated restructuring of group work classes, linked to the lecture, led to an increased and more structured emphasis on case studies sourced from Texas AMU (Prichard, 1992). These studies contrasted with high profile cases routinely encountered in the literature (and presented the previous year) in that they emphasised the importance of acting ethically throughout one's professional career. The initial case study involved an Engineering student, who needed to question standard practices in a factory. The final study implicated personnel at management level in a conflict of interest case. The case studies also served to underscore the implications of ethical decisions not only at the personal level, but also to society.

Previous poor student engagement suggested that general discussion, based on collective opinions of the potential issues from different philosophical perspectives was ineffective. Reappraisal of educational methods in the literature suggested that role playing may be an appropriate means of deepening understanding of unfamiliar subject matter (Prince, 2006). Moreover, class participants were already familiar with this method and had responded favourably to it previously in the Communications module. The exercise completed as small group work required separate groups to assess different case studies. Different members of each group advocated different perspectives on a problem, e.g. a client, an environmental regulator, or a member of the public. Presentation of the different perspectives in each case study to the rest of the class was followed by feedback, in which other small groups judged the effectiveness of individual arguments. Finally, the class evaluated how the SEP applied to the overall issue, and how the Engineer should act most responsibly.

Case study evaluation deliberately began with those topics most relevant to students/recent graduates and progressed to issues that may be confronted senior professionals. This approach aimed to underscore the point that Ethics remains a crucial issue throughout an Engineer's career. Formative feedback provided during the class demonstrated an improved student understanding of potentially significant issues and the relevance of the entire SEP (rather than individual concepts) to the topic solicited from other groups.

As in Year 1 the Introduction to Ethics lecture and role playing exercise provided a basis for a summative small group activity, which required students to source a case study with relevance to Engineering Ethics. The case studies chosen ranged from the Titanic disaster and the Heathrow Tunnel Collapse, to the Kansas City Hyatt Regency Walkway Collapse, although issues of local relevance were marked preferentially. Each group presented its case to the rest of the class as an oral presentation, and to the module co-ordinator as a written group report. Groups received bonus marks where they demonstrated the ability to integrate more than one point from the SEP into their arguments and responses.

Outcome and Follow-up

Of the 21 groups of 5-6 students, 10 received grades of over 70%, with the lowest grade being 58%. Overall average mark was 67%, which lay within the expected range for the module marks, as outlined by School grading policy. While of course one must be cautious in interpreting student grades, we feel the student group work did give us confidence that the majority of students demonstrated a good grasp of the Statement of Ethical Principles and were able to demonstrate how they could be applied to 'real life' Engineering situations.

Following case study presentation, each group of students was required to 'map' the four principles in the Statement of Ethical Principles onto their case study and then answer the following question 'How does the statement of ethical principles relate to the principles of Sustainability in Engineering?' The question aimed to provide further opportunity for groups to reflect on the impact of microethical Engineering decisions on Society, and how these decisions may in fact have a macroethical component. The outcome of the post-presentation evaluation suggested significant improvement in student understanding of the topic. All but three groups recognised the ethical responsibility of Engineers to society, and the importance of developing designs with the longer term needs of society in mind. Twelve groups explicitly related the SEP to the principles of Sustainability; with a further four groups acknowledging potentially wider implications for society. The 'Post-presentation evaluation' returns from each student sub-group thus suggest that the requirement to 'map' the group case study to each of the four RAE Ethical Principles provided an improved approach to learning and testing/verifying student understanding of the applicability of these ethical principles.

7. CONCLUSIONS AND RECOMMENDATIONS

a) The use of small group work (both in terms of small group discussion and group projects) indicates that the gap identified between the staff-centred concerns on teaching a curriculum and the student-centred experience of 'learning' can be overcome within facilitated and guided experiences. Within the small group discussion or project context, students can learn from each other, thus both facilitating and encouraging more independent learning and also providing opportunities for deeper learning.

b) An important part of this process is honest and frank staff evaluation of the teaching and learning. In terms of interdisciplinary team teaching this is vital since it is most often the case that colleagues from different disciplinary backgrounds, different research and pedagogic cultures need to get to know one another, understand each other's intellectual frames of reference, concepts and so on.

c) Within the context of having limited space for integrating ethical considerations within the Engineering curriculum, all core modules should have some ethical component, rather than the provision of a stand-alone ethical module which is semi-detached from other modules. The stand alone approach can lead to the danger of a 'tick box' approach, feeding into student (and perhaps staff) perception that Ethics is not a core aspect of the Engineering curriculum but an 'externally' imposed requirement (from the RAE or other accrediting professional body). Additionally, consideration should be given to integrating Engineering and non-Engineering students within the Ethics component of the curriculum, as suggested by Graber and Pionke (2007), perhaps, as indicated above, using 'Sustainability' as the focus for a dialogue between Engineering and non-Engineering (social science and humanities) students and courses.

d) The RAE Guiding Principles for Sustainable Development provide a useful frame of reference for Civil Engineering students to understand the implications of professional decisions on wider society and how microethical issues may have a larger macroethical aspect. Student familiarity with the guiding principles provided a useful means for embedding technical issues into a social context and subject matter with which students were otherwise unfamiliar.

When teaching Engineering students Ethics, one needs to bear in mind that the language and concepts used need to be appropriate to their level of ethical understanding. It is critical to avoid abstractions outside of their domain of interest. We firmly believe that everyone is and ought to be 'ethical' – in the sense that there is a basic, intuitive perception of 'right and wrong' and that one does not need ethical training to discern ethical from unethical behaviour. That said, within the formal university setting against the backdrop of a professionally accredited degree course and most importantly with a full understanding of what it means to view Engineering as a 'profession' (like the medical, or legal profession), it is imperative that students understand the privileged position they will have once they qualify. With the power, authority and public respect of being a professional Engineer comes responsibility; to understand oneself as a 'Professional Engineer' must mean thinking of oneself as a type of person who does not do certain things. Here we come closest to the notion that perhaps has motivated our approach to teaching Ethics to Engineers, that it is about character, the active reflection upon and creation of a sense of oneself as a professional Engineer who cultivates the 'habit' of being ethical, of working with the letter and spirit of codes such as the RAE's Statement of Ethical

Principles, such that one's professional practice becomes a matter of who you are and aspire to be, rather than thinking 'being ethical' always is a matter of having 'external' rules 'imposed'.

The findings of this study have indicated that Engineering students, when presented with appropriate subject matter – in this case placing Engineering within the wider context of Sustainability and the interdisciplinary challenge of the transition towards Sustainability - can learn and apply ethical concepts to problems relevant to their day to day professional practice. Nonetheless, there remains room for improvement. This study forms part of a longer term iterative approach in which the most appropriate means and techniques for teaching Engineering Ethics will be further developed and adapted in teaching Civil Engineering students.

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The Role of the Professional Engineer in the 21st Century

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Abstract: In light of the current world economic and environmental crisis due in part to unsustainable development and poor financial planning, 21st Century engineers are faced with unprecedented challenges of developing a sustainable world in balance with the forces of nature to combat global environmental, social and economic crises. The European Union, the United States of America and a number of other countries have identified that smart solutions and highly skilled professionals are needed to survive climate change and create long-term prosperity. In this paper the evolution of the changing career of the engineer will be presented. The policy background to the current system of engineering education at bachelor's and graduate level in Ireland will be introduced and perceptions of engineering as a profession by society in general, and by school leavers selecting third level courses will be discussed. The role of the engineer as a specialist, expert or generalist will also be studied in terms of the changing demands and needs of society. Finally the responsibility of universities, through broad-based multidisciplinary teaching and training, to prepare the next crop of engineers will be examined.

Keywords; Chartered engineer, Industry, Multidisciplinary, Professional engineer, Sustainable development.

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1. INTRODUCTION & POLICY BACKGROUND

The development of the modern world has been dominated by science, engineering and technology and the role of the engineer is linked closely to the needs of society. Unfortunately engineers are either public relations shy or poor communicators of their success. As famous scientists tend to develop medicines, they appear to be viewed by society in a more philanthropic light. The term engineer used in this paper includes any professional scientist, technologist or engineer who uses her skill sets and training to develop practical real world applications. Engineering is not a stationary profession; it is continuingly evolving to include new sub-disciplines. The 21st century will be defined by some of the huge challenges now facing humanity. Among these are energy and food security, competition and scarcity of natural resources, and climate change. This year's engineering graduates will face these issues throughout their working careers. The demand for engineering skills is likely to be higher than ever before in order to deliver sustainable engineering systems, low-carbon energy technologies, and robust physical infrastructure to protect against geophysical hazards such as sea-level rise and extreme meteorological events.

At a local level, Ireland faces all of the above issues to some extent, as well as the pressing additional short-term challenge of dealing with a severe financial crisis, and reducing unemployment in particular. Government policy aims to support long-term economic recovery through the creation of a “smart economy” [1]. This vision for a smart economy will feature increased levels of investment in research and development by indigenous companies and by multinational companies. Additionally, the provision of high quality infrastructure and growth in renewable energy and so-called “green collar” jobs will support this endeavour. The US federal stimulus programme places a similar emphasis on job creation in what has been termed the “green tech” sector. Government policy on education is aligned with the goals presented in the Smart Economy vision. A national strategy for science, technology and innovation has the stated goal of doubling the output of PhD graduates between 2004 and 2013 [2]. Figures compiled by the US National Science foundation in 2004 [3] showed that Ireland’s per capita output of PhD graduates was well below that of countries such as Finland, Switzerland and the UK. However, Ireland’s PhD output in Science and Engineering disciplines was somewhat better, and is likely to have improved significantly improved since the NSF data were collated. The authors of the government strategy hope that increasing PhD output (and the associated increase in the numbers of postdoctoral researchers and principal investigators) will drive innovation through industrial R&D and the transfer of skills into the enterprise sector, thus reducing the country’s reliance on foreign direct investment (FDI) as a source of jobs and tax income to support public services. The mobility of FDI, which constantly seeks lower-cost operating centres, has been to Ireland’s advantage, and latterly, disadvantage, which means that it is an unreliable revenue generator for the future.

2. INTRODUCTION & POLICY BACKGROUND

The main focus of the scientist is to develop knowledge and understanding of the physical universe [4]. Science is the pursuit of knowledge in its purest sense without any concern to the needs (or interpreted needs) of society, whereas engineering is the combination of both. A simple Venn diagram in Figure 1 shows the interaction of engineering, science and society adapted from Reference [5].

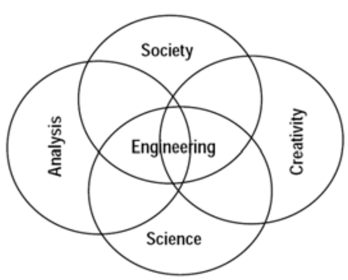

Figure 1 Engineer in Society

Engineering connects pure science to society. Unlike science, in engineering the environment in which engineers plan, design, build, manufacture, maintain and operate continually changes and so the engineer must be prepared within an ‘acceptable level of risk’ for all possibilities and outcomes. In a controlled laboratory there is much less chance of an uncertain event. The biggest risk factors in engineering are planning for the unknown behaviour of humans and natural systems. In an article entitled ‘Engineers, Terrorism and Creationism’ published in the New Scientist in 2009 some interesting claims were made about engineers [6]. The article was widely quoted and discussed at the time, and was based on the findings contained in a Department of Sociology, University of Oxford working paper produced by Diego Gambetta and Steffen Hertog [7]. In one simple article more damage was done to the reputation of engineers than centuries of bridge building and service to society. The study carried out by Gambetta and Hertog concentrated on a particular religious group in a specific geographical area and obviously the data were skewed from the start. Engineers have contributed very largely to society, but are a misunderstood group, as their efforts are often under-appreciated. Delivery of most of the services essential to modern life such as electricity, flight, television, medical imaging, sewage networks, the telephone, water networks and railway lines are the result of engineering. Engineers plan, design and create the physical structure through which society lives, works and plays. Therefore in order to appreciate and understand the role of the engineer in the 21st century we must examine the relationship between the engineer and society. Then, perhaps 21st Century engineers can develop a sustainable world in balance with the forces of nature to combat some of the inventible global crisis if given the opportunity. In this paper the evolution of the changing career of the engineer is presented. The role of the engineer as a specialist, expert or generalist will also be studied in terms of the changing demands and needs of society. Finally the responsibility of universities through multidisciplinary teaching and training to prepare the next crop of engineers will be examined. This study is based on some freely available statistics and figures from Ireland.

3. Engineering Educations in Ireland

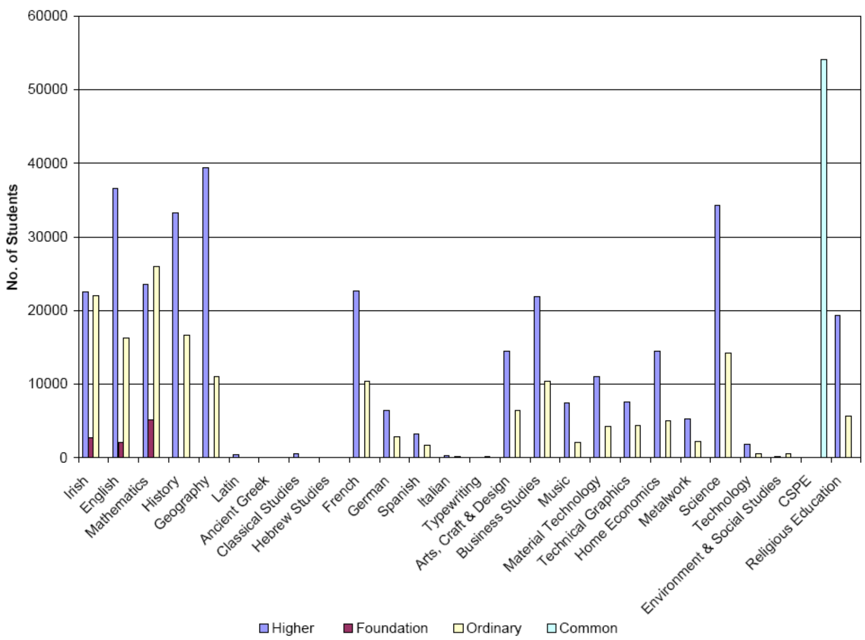

Figure 2 No. of Students per Subject Junior Certificate 2009

The Irish secondary school system (ages 12-18 approximately) is divided into two cycles, a three or four-year Junior cycle followed by a two or three-year Senior cycle. The cycles culminate in the state-run Junior and Leaving Certificate examinations. Figure 2 shows a breakdown of the 2009 number of students per subject at the Junior Certificate level [8]. There are 34 subjects taught at Leaving Certificate level with an additional number of European Union language subjects available upon request. In 2009 there were 49 subjects taken. Entry to University or third-level colleges is determined by a point score, derived from grades awarded in the Leaving Certificate examinations. The core Junior Certificate subjects change at the Leaving Certificate level to Biology, Geography and Business along with English, Irish and Mathematics. So how do subjects, such as honours Mathematics, History and Science, so popular and successful at Junior

Certificate level, fail to attract interest at the Leaving Certificate level? Anecdotal evidence from the authors' own school days (20 years ago) that history, mathematics and physics and chemistry are perceived as tough, long courses where it is difficult to achieve a high grade. The statistics seem to indicate that the situation has not improved.

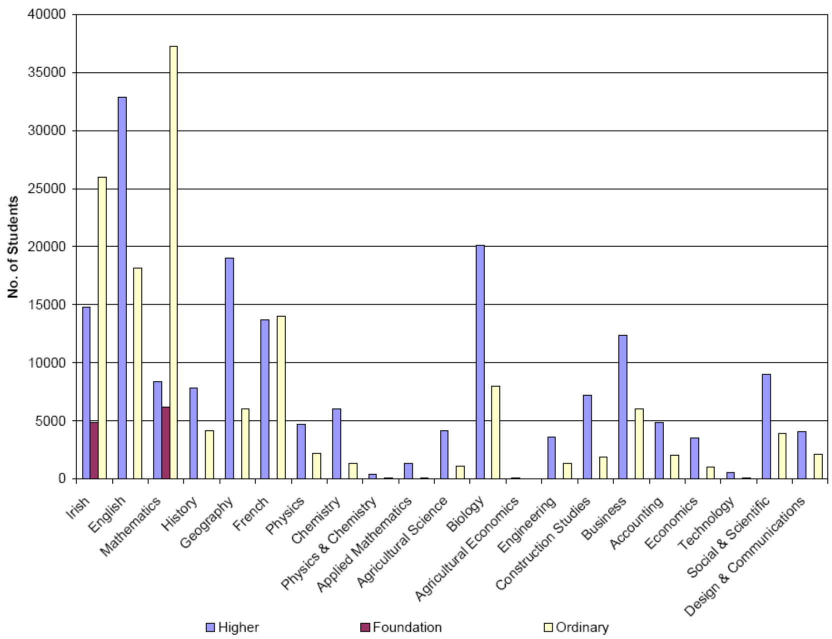

Figure 3 No. of Students per Subject Leaving Certificate 2009

A review of the course syllabi, content and examination papers of the years up to 2009 supports this statement. Students are becoming cannier, the examination papers are more predictable and in the era of Celtic Tiger students learned that the total number of points (irrespective of the subjects) is the measure of academic success. Nowadays, full marking schemes are made available after the examination, together with model answers. A student like everybody else in life would take the path of least resistance and in this instant the statistics prove with the tapering off of history, chemistry, physics and mathematics suggests that this is the path less travelled. Geography and biology maintain their popularity from junior to senior cycles. Figure 3 shows the breakdown of subjects taken at Leaving Certificate level in 2009. The difference between the core subjects at honours and ordinary level from Junior Certificate is interesting.

What does this indicate? The student is making a practical decision to maximise their lifelong opportunities by avoiding the subjects with the most constraints. To the uninitiated it indicates that these subjects with the same amount of effort produce a better chance of success. If we carry this mind-set through then it is easy to postulate that second level students examine the choices available at third level and again make their choice on the path of least resistance. Obviously potential earnings, career advancement and job security play an important role in their ultimate choice, but unfortunately these are rarely guaranteed in engineering. Second level students struggle when asked to name a famous engineer, whereas Marie Curie, Louis Pasteur and Albert Einstein are readily named as examples of famous scientists.

Every year there is media attention given to the 'problem' that we do not produce enough engineers. This could be attributed to the honours Mathematics entry requirements into some engineering courses. In science the number of enrolments holds fairly steady year on year [9]. The question is, do we really need any more scientists and engineers than we already produce? More PhD degrees are awarded in the sciences than in any other field in the world annually [10]. In engineering a PhD is not an industrial norm in R&D, whereas it seems to be a prerequisite in many fields of science. Some argue that the education is an indicator of economic success of a country and figures from the Organisation for Economic Co-operation and Development (OECD) seem to support this assertion [10]. However, to what stage of education and to what degree of financial support? The following are some statements from the same OECD report:

- *'Investment in research and development (R&D) for the environment in so-called clean technologies such as renewable energy (+20%) to air pollution control (+12%) to mitigate climate change effects increased substantially from 1996 to 2006 (OECD, 2009).*
- *Scientific studies are more popular in Korea and the Nordic countries, where science and engineering (S&E) degrees account for 37% and 29%, respectively, of total awards. In most OECD countries, universities deliver more engineering than science degrees.*
- *OECD governments are concerned about the low level of female participation in scientific studies. The presence of women is overwhelming in humanities and the arts (67%), health (74%) and education (75%) but low in engineering (23%) or computing (23%). 40% of OECD doctoral students graduate in scientific fields; the S&E orientation of doctoral programmes is even more pronounced in emerging countries.*
- *In many OECD countries doctoral degrees have multiplied faster than other university degrees. Despite their greater propensity to graduate at tertiary level, women represent on average 46% of tertiary-level employment. Earnings differentials between males and females still remain significant in all OECD countries.*
- *Foreign affiliates provide access to new markets and new technologies for domestic firms. In 2006, the share of firms under foreign control in total turnover in manufacturing varied from about 80% in Ireland to 3% in Japan.*
- *The share of foreign affiliates in industrial R&D varies widely across countries, ranging from 5% in Japan to over 60% in Ireland and the Slovak Republic.*
- *Doctorate holders have a research qualification and are a pillar of the research system. Their presence is an indicator of a country's attractiveness for new and foreign talents. Employment of doctorate holders ranges from 97% to 99% and exceeds that of university graduates (83% to 89%).*
- *Many doctorate holders face temporary employment in the early stage of their careers. After five years of activity, 60% of doctorate holders in the Slovak Republic and over 45% in Belgium, Germany and Spain remain under temporary contracts. Yet permanent engagements account for over 80% of all jobs in almost all countries.*
- *The earnings premium from education is an important incentive for individuals to enrol in tertiary education. In all OECD countries, annual earnings increase with educational attainment levels. In the Czech Republic, Hungary, Portugal and the United States, the average earnings premium for a tertiary-level diploma holder was no less than 75% in 2006. Such differentials are traditionally smaller in Nordic countries and lower than 30%. Over the past decade, the earnings premium of highly skilled workers decreased the most in Italy (–6.4%), Ireland (–4.3%), Hungary (–4%), Germany (–3.4%) and Poland (–2.9%). The opposite trend is observed in Australia, New Zealand, Spain and Sweden it increased at an average annual rate of between 1% and 3%.*

In Ireland generally one third of all PhD students are enrolled in the Science disciplines and headcounts indicate that a third go on to academia, a third go onto to private sector R&D and the remainder find some other type of employment [9]. This does not include Engineering. Figure 4 shows actual PhD graduation statistics from 1999 to 2008, for all disciplines and by gender.

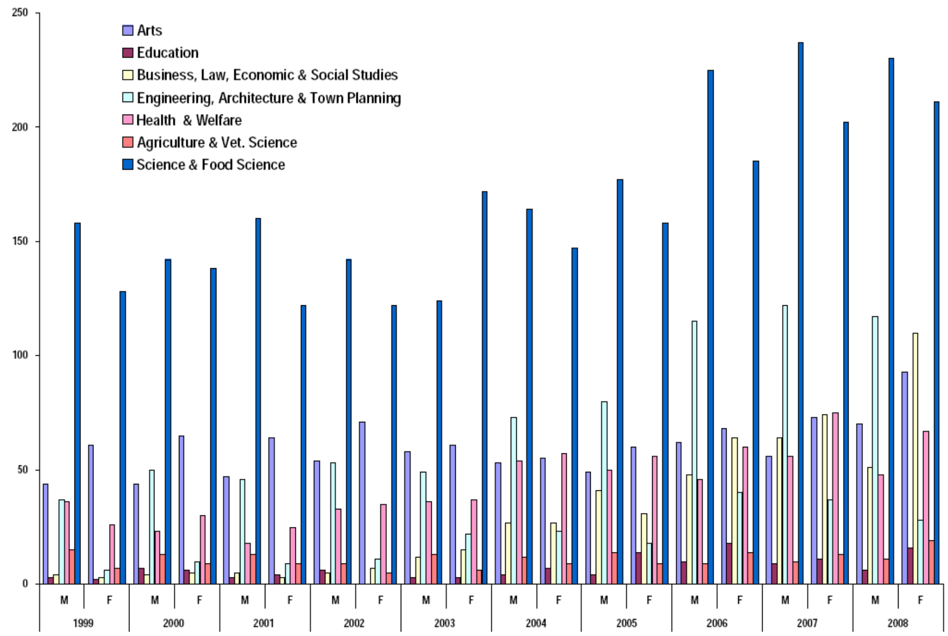

Figure 4 PhD graduation statistics from 1999 to 2008 [9]

The National Development Plan (NDP) 2007 – 2013 put higher education at the heart of national policy and the following were identified as needs to be addressed over the lifecycle of the plan [11]:

- *'Increased participation and improved access;*
- *Encourage a greater flexibility of course offerings to meet diverse student population needs in a lifelong learning context;*
- *Promote the quality of teaching and learning;*
- *Significantly increase PhD numbers and research activity;*
- *Effective technology transfer; and*
- *Safeguard and reinforce the many roles of higher education in providing independent intellectual insights and in contributing to our broader social, human and cultural understanding.'*

Are third level institutions producing the calibre of graduate engineer really up to the demands of industry? Anecdotal evidence in Ireland over the last number of years seemed to indicate that there was some unease with the grades awarded to students and their actual ability in the private sector. Nearly a third of every graduating engineering class had a first, compared to perhaps only 3% twenty years earlier. Yet, these graduates seemed to lack the simple fundamentals of engineering and professional etiquette. Recently this garnished some media attention [12]. There are reports, which seem to indicate that there is some grade inflation (to varying degrees) since 1996 [13 and 14]. A report in the United Kingdom produced when there was similar rumours, concluded that students must be working harder [15]! This is not a new phenomenon and internationally these concerns are raised and discussed regularly. The question should be asked of engineering and science, does it require a certain level of numerical ability and if we loose our minimum entry requirements are we really producing the right calibre of graduate for industry?

During the late 20th century a trend towards greater specialisation was apparent, with bachelor's degrees being offered in specialised niche areas such as biomedical engineering, optoelectronics, mechatronics, building services engineering etc. This was particularly the case in the UK but also occurred in Ireland. There are currently 78 honours engineering degree programmes offered in the Republic of Ireland [16]. Of these, 21 could be said to be in niche areas including biomedical engineering, transport technology, sports and exercise engineering and multimedia systems. Only 8 of the courses are described as general (undenominated) engineering upon entry. Engineers and scientists have created incredible technology using their minds, logic and cognitive abilities for the betterment (in most part) of society. It is time for us to upgrade and sharpen our scientific minds to integrate diverse perspectives. The new globalisation paradigm requires adopting new tools to turn our altruistic nature into a positive force to take control of the policies, which shape our world. Engineers and scientists know how to make this world sustainable and support us all, but can society accept this? Perhaps the profession of engineers needs to embrace a student with better sales skills and lower mathematical and analytical skills? Otherwise will our accumulated knowledge continue to be limited to the 10 minute power point briefing session presentation? How do we encourage such students into our ranks, if from they are lost when they make their subject choices for the Leaving Certificate? Can an engineer's communications skills really be improved? Better career opportunities, which of course include salary and management opportunities, may encourage students with the same scientific ability into engineering.

Albert Einstein is quoted for saying many things, but perhaps one of his less cited quotes is '*Science is a wonderful thing if one does not have to earn one's living at it*'. The same could also be said about engineering. Engineers and scientists tend to earn far less than other professions with comparable educational requirements. The famous cartoon character Dilbert's 'Salary Theorem' states that '*Scientists and Engineers can never earn as much as administrators and sales people*.' Aside from the salary an engineer or scientist who pursues such a career knows from the onset that the career opportunities aren't that great, but they do perceive challenges and continually training and knowledge advancement, sadly this is not always the case. This raises the issue of the specialist versus the generalist. In engineering if an employee is pigeonholed as an expert in a specific area, such as traffic, circuit design, programming, concrete design, computer aided design (CAD), or report writing, it can paradoxically become career-limiting, as the scope for career advancement opportunities reduces. Every engineer finds this limiting and it goes against their very nature. There are numerous engineers, particularly in local authorities where the opportunity to change area or focus is very rarely available. This does not give the tax payer value for money. At the end of the day the purpose of the engineer whether in the private sector, public sector, semi-state or academic world is to be productive, sometimes the productivity can be very slow due to the nature of the environment. In this new 21st Century era of limited resources engineers must be smarter and climb the hurdles of mediocrity placed in our way to guarantee a better society for all.

4. Discussion & Conclusion

The challenges of sustainability and responding to climate change, outlined in the introduction, will define the careers of 21st century engineers. It is likely that engineers will have to work across the traditional boundaries of sub-disciplines such as electrical, mechanical, civil and process engineering in order to meet these challenges. The authors believe that this will necessitate a shift in how engineering is taught in third-level education, reversing the trend of recent decades towards increasing specialisation at undergraduate level, as generalists will be more likely to be able to tackle the cross-disciplinary aspects of the challenges of the 21st century. In this respect, a shift towards multi-disciplinary thinking, where engineers with a broad-based education can quickly adapt to different areas, rather than inter-'disciplinarity', where multiple specialists remain within their own disciplines but attempt to collaborate to solve problems, is more likely to succeed. Therefore the authors envisage a return to the more broad-based engineering degree programmes which were prevalent in the mid-20th century, with a solid emphasis on mathematics, mechanics and physics in the early years before specialisation is encouraged. This paper has examined at a high level the role and development of the engineer in society in the 21st century. It has identified and discussed areas of concern to the engineer, including the calibre of graduate, career advancement and opportunity and grade inflation and the measurement of success in academia. Engineers have much to offer society, but this can only be done if engineers actually participate in society. The current portfolio of engineering courses offered by third level institutes will have to change in order to equip this generation of engineers to deal with the challenges of the 21st century.

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IMPLICATIONS OF SECONDARY LEVEL STEM EDUCATION ON ENGINEERING STUDENTS IN NORTHERN IRELAND

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Abstract: In 2009, the Department of Education and Department of Employment and Learning (NI) issued a report highlighting the challenges faced in ensuring that the supply of Science Technology, Engineering and Mathematics (STEM) qualified individuals continued to grow in response to demand within the local economy. Over the past decade, there has been a steady decline in uptake of secondary level STEM education, and based on workforce demand in the STEM sector there is a significant predicted shortfall in supply over the next decade. The report presented a series of 20 recommendations for action to promote renewed economic growth through STEM, and highlighted shortfalls in STEM education and careers advice particular to the Northern Ireland education sector. This paper presents an overview of the NI STEM report from the perspective of a tertiary level engineering school, and summarises the findings of a survey undertaken by the authors in a bid to understand how this will affect future generations of student engineers. In particular, a stark gender divide has been identified in how careers advice is regarded at secondary level, and there is a clear need for more to be done to assist in decision making processes at all key transition points.

Keywords; Student recruitment, Retention, Secondary level education

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1. INTRODUCTION

Over the past ten years, there has been a marked reduction in the percentage of students entering into STEM (Science Technology Engineering and Mathematics) related career paths within Northern Ireland, which has significant consequences for ensuring economic stability and growth in an increasingly competitive marketplace. The recent All-Island Skills Study (2008) highlighted the continuing importance of engineering within the economy (nearly 110,000 jobs in both the North and South of Ireland were based in engineering at the point of survey) and a continuing need to develop these skills has been identified through both the Northern Ireland Success through Skills (2008) and the Tomorrow's Skills (2006) programmes. With this impetus, a joint study was undertaken by the Department of Education (NI) and the Department of Employment (2009) in the Spring of 2007 to examine these trends and to comment on the implications for the future of the NI workforce. While many of the factors observed are common across the whole of the UK (the increasing apathy at younger ages for STEM related subjects, limited careers guidance at key transition points and a general lack of Continuing Professional Development activities for STEM educators at a secondary level were all identified), a number were unique to Northern Ireland, in particular to those relating to student achievement, the substantial reduction in the numbers taking A-Level Physics and gender balance within the STEM area. These factors have implications for the numbers of students entering into higher education engineering degrees as they all lead to a reduction in the number of suitably qualified individuals, and to this end the School of Mechanical and Aerospace Engineering at Queen's University Belfast has been examining in more details the implications of the findings of this report with relation to the recruitment and retention of undergraduate engineering students.

2. RECRUITMENT AND RETENTION TO STEM

Despite the continuing need for STEM qualified individuals within the workforce, examination of statistics over the past 10 years indicate that there has been a sustained decline in students graduating from tertiary level STEM subjects across the whole of the UK (relative reduction of almost 3.5%), with the most pronounced drop in Engineering and Physical Sciences (Figure 1).

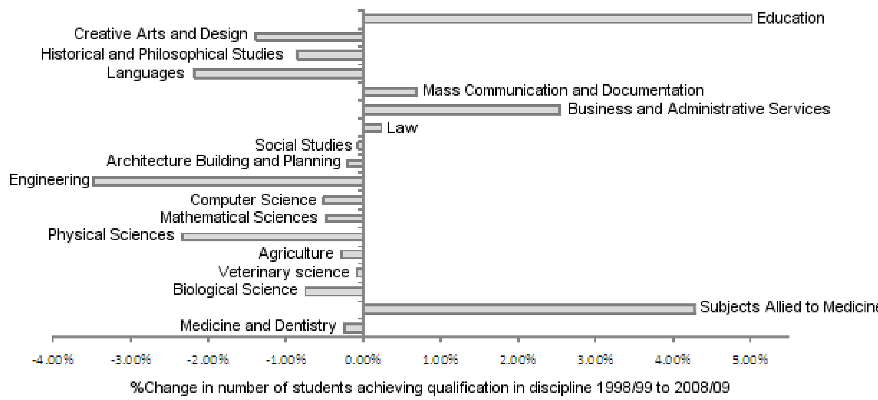

Figure 1 Evolution of population of graduating students (NI STEM report, 2009)

This is apparent across nearly the entire STEM sector, with the exception of those subjects allied to medicine which has seen a remarkable growth across the same period. It is cause for concern when many of the employment forecasts indicate that the largest growth will be in the STEM sector (Figure 2), with significant demand for graduates with a solid physical sciences background (encompassing the skills that an engineering graduate would obtain). By 2020, based on the current rate of contraction of the STEM supply, it is predicted that there will be nearly a 65% shortfall in workers trained in physical science based careers relative to baseline demand. This is particularly concerning in light of new regulations which no longer require a balance of sciences to be taken to a GCSE level within Northern Ireland (introduced 2007) which has resulted in a significant drop in students electing to study all three sciences in some combination to at least GCSE level. In the first year of introduction of this regulation, the numbers registering for GCSE Double Award Science was reported to fall by 16%, accompanied by an increase in entries to the individual sciences - GCSE Physics reported an increase in registrations of 33.3%. However, on balance this actually represents a net-loss of students who are qualified to undertake A-Level Physics of approximately 7%. For the same year, it should also be noted that the relative uptake of GCSE Single Award Science in NI was nearly three times that of the rest of the UK, again representing a significant loss of students into the STEM pathway as this course is not designed to advance students to higher level STEM education. As a solid appreciation of physics is desirable, if not essential to the engineering undergraduate, this substantial reduction in students undertaking even basic physics education at the age of 14 has the potential for significant impact downstream on intakes into engineering degree programmes.

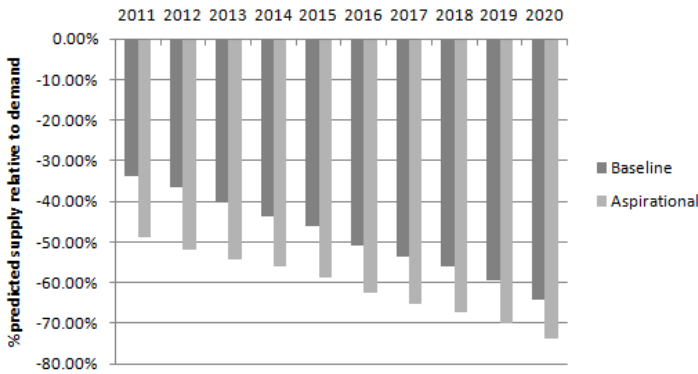

Figure 2 % Under-supply up to 2020 in physical science based careers in NI (NI STEM report, 2009)

In order to tackle these recruitment and retention shortfalls, the joint study proposed a series of 20 recommendations for action, which can be categorised into four main areas:

- Increased business engagement in STEM education is required.
- Constraints within the STEM education artery need to be alleviated (or, where possible, removed).
- There is a need for increased flexibility in STEM education.
- Government support for STEM education initiatives needs to be significantly improved.

While the report recognised that there were a number of points within the educational pathway at which students were leaving STEM education, the cause of many of these factors is not entirely clear. As the low uptake in physics and low percentage of females entering into STEM are of particular concern as this ultimately reduces the pool of capable individuals suitably qualified to enter into engineering career pathways, ways in which these trends can be addressed, and potentially, reversed, are essential to ensuring that there is a continuing pool of capable engineering graduate passing into the workforce when they are most in demand.

3. SOURCES OF IMBALANCE

One of the key foundations of an engineering degree is a solid appreciation for physical sciences, but the trends in Northern Ireland across the last ten years have shown that the numbers of students in Northern Ireland enrolling for A-Level Physics is dropping dramatically at roughly a rate of 3-4% per annum, despite NI significantly outperforming the rest of the UK in A-Level Physics results. There has been a subtle, but distinctive shift across that time in the combinations of STEM subjects undertaken, with a move towards combinations including biology and chemistry (the numbers of enrolments for a combination of A-Level Biology and Chemistry has risen by nearly 18% over the last ten years) at the expense of the more traditional subjects for engineering (the combination of A-Level Physics and Mathematics has decreased by nearly 20% in the same period). The NI STEM report indicated that a number of these factors could be traced back to early in the educational process (with indications of dissatisfaction with STEM subjects evident as early as Key Stage 3), but while it clear that students are disengaging from physics at a number of key points within the STEM educational pathway, it is not entirely clear why this is so stark in Northern Ireland in comparison to the rest of the UK.

To attempt to understand this, a sample of ~400 students from Queen's University Belfast were surveyed to examine the experiences of students with secondary level STEM subjects and, in particular, to identify reasons why students were being put off physics at such an early point in their careers. The questionnaire was distributed electronically, with the questions formulated against a number of the recommendations which have been put forward from the DEL/DE joint panel. In particular to students who would be entering into engineering careers, two of these recommendations are of particular interest:

- How clear are the STEM career pathways in Northern Ireland made to secondary level students?
- Is there a quantifiable gender bias in NI STEM education, and if so, is there a clear source?

This initial student survey was then supplemented with interviews with student teachers currently enrolled on the Queen's University Initial Teacher Education course to examine the challenges that teachers face on their first exposure to STEM teaching in the Northern Ireland education system.

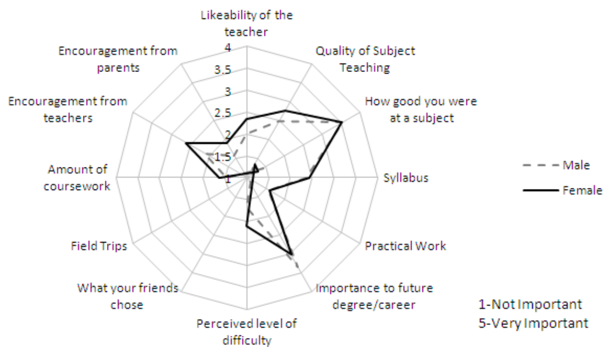

Figure 3 Influences on A-Level subject selection

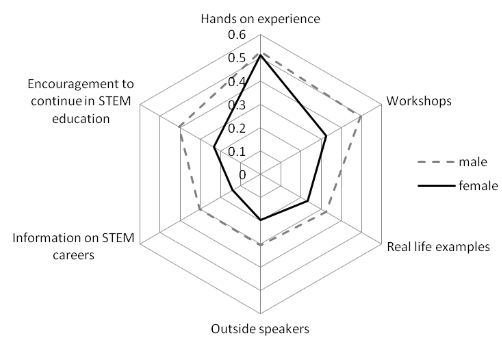

Figure 4 Perspectives on Careers Advice in NI (split by gender)

After analysis of the questionnaires, it became clear that there was one issue which was common to nearly all the students questioned. When considering subject selection, beyond aptitude for a subject, the dominating influence was the importance of that subject to a future career pathway (Figure 1). However, there is a general feeling that there is a lack of sufficient information about careers and pathway options available within schools to support this, and students are not always aware of how the subjects selected for study at A-Level would impact on future career choices - 68% of those surveyed did not feel they had received an appropriate level of careers support from their schools during the subject selection processes. The students placed much more value on access to individual careers advice within their schools during these times rather than on the more traditional careers support mechanisms such as careers fairs, workshops and school visitors.

This perceived lack of careers advice becomes even more of an issue when it is examined by gender – 77% of females questioned did not believe they had received adequate careers advice (compared to 55% of males), emphasizing a lack of all round careers support in their decision making processes, much more than the male respondents. From the perspective of students who had undertaken at least one A-Level STEM subject, it was indicated that there is a general lack of information available to them on STEM career pathways combined with a lack of encouragement to progress in STEM subjects. This was particularly prevalent in female students' experience (Figure 4). In both instances (male and female), schools are falling far short of student expectation in the delivery of careers related information.

For those students who considered engineering as a career option (representing 38% of the respondents), there are again significant differences in the responses which were obtained from by gender regarding the careers support that they received in School.

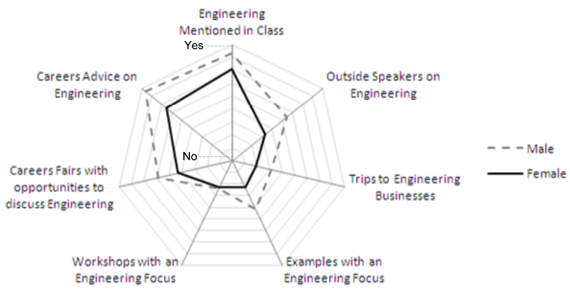

Figure 5 Types of Careers Advice in NI (split by gender)

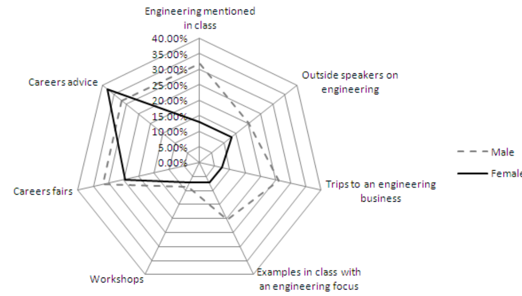

Figure 6 Desirable Career Decision Aids

Female students who would have considered engineering as a career option reported that they had less access to engineering-focussed careers information relative to their male counterparts experience (Figure 5). This included less likelihood to have had access to outside speakers to discuss engineering careers (M: 54% F: 34%), and also less likely to have had access to individual engineering careers advice in their schools (M: 86% F: 65%). When asked what they would have found useful when making careers decisions, there is a definite need for individually tailored careers advice, but there are again distinctive differences in the male and female perspectives on useful activities. Female students are strongly in favour of good careers advice and access to careers fairs to help in their decision making processes (which is of concern, as this is something many of them feel has been lacking), while male students would prefer a more rounded approach incorporating visits, speakers, class work along with the careers advice (Figure 6).

As physics has experienced the greatest downturn in numbers relative to the other traditional science subjects (and is core to engineering), the students were questioned about their perception of physics relative to its counterparts. The responses to this were largely similar for both genders (indicating that the main source of gender bias possibly relates to the lack of careers focus attached to the subject rather than the subject itself). On the whole, the student experience of physics was less favourable than its comparitors - physics teachers were perceived as less knowledgeable about their subject, less able to provide hands-on experiences and classes were less fun (Figure 7). 80% of students felt that there was too little careers advice given about how physics could be used in later life (as opposed to that which was observed linked to Biology and Chemistry), limited encouragement to pursue it (70%) and too little linkage to real life (74%).

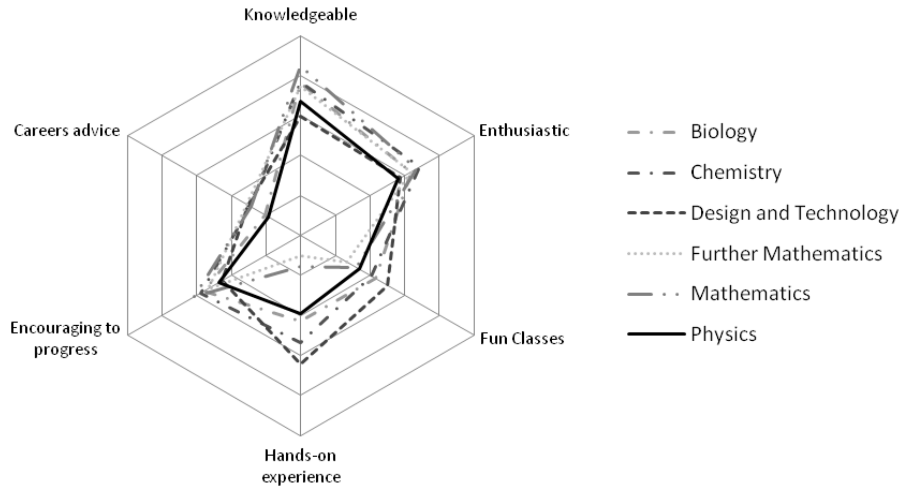

Figure 7 STEM Classroom Experience

The expressed lack of confidence in the ability of physics teachers is interesting, particularly in light of the recently released numbers indicating the make-up of the secondary level STEM teachers in Northern Ireland which indicate that there is a significant shortage of physics teachers - there are less than 200 registered physics teachers in Northern Ireland, which represents less than a third of the overall number of biology registered teachers, and the age profile indicates that nearly 50% of these teachers are approaching retirement (NI STEM report, 2009). This shortfall in teachers is being covered through the use of non-subject specialists at Key Stage 3 – at the time when students are making choices which will influence their future career pathway, and the point at which the first large drain of students from the physical science based pathways was observed. Non-subject specialists taking on this role at such a formative point of the educational pathway is cause for concern given that studies of physics education have demonstrated that there is a clear link between whether the teacher is a physics subject specialist or not and the level of achievement of their students in physics examinations (Smithers and Robinson, 2005).

Some of the comments from the students regarding their careers and their experience of careers advice in Northern Ireland paint a depressing picture, reinforcing the problems with careers information, encouragement and information about pathways:

1. Careers classes focussing on application procedures rather than actual career pathway advice:

“Careers classes in school were ….. learning how to apply to university”

"my careers class always focused on applications to university and fees.….. however it won't help you choose the career path which is right for you."

2. Lack of encouragement for females into engineering:

“I went to a girls school where it (engineering) was hardly mentioned. I resented this as I had a particular interest in the subject.”

"Girls are seriously not made aware of engineering as a career choice…… I also found that I received not much encouragement with my choice."

3. Careers teachers with pre-conceived notions of career pathways:

“I was …. encouraged to "know my limits" and was not asked my opinions.”

"Teacher input was more focused on telling me what they thought I should do rather than helping me make my own choice or even asking me what I wanted to do and encouraging me to follow my instinct……."

4. OBSERVATIONS ON STUDENT EXPERIENCES

The lack of adequate careers advice at an early stage in the educational pathway reinforces the findings of a number of previous studies undertaken by the IET in 2007 and 2008 which indicated that there is a general lack of good quality careers advice available in schools which is having a negative impact on the uptake of STEM subjects. However, this appears to have more significant consequences when examined by gender: female students appear to place significant emphasis on individual careers advice for decision making, much more so than their male counterparts, and were, on the whole, receiving less (or at least had the perception that they were receiving less) career-focussed information in support of their decision making processes. This has a number of consequences that need to be considered:

1. Female students place increased emphasis on careers advice for future planning, but feel they are receiving an insufficient quantity of this within schools.
2. Current trends indicate that future work opportunities are likely to lie in the science and technology field, which currently has a significant gender imbalance in most sectors.
3. Female students require focussed individual careers information as early as pre-GCSE subject selection to highlight career pathways and future opportunities to assist them in their career planning, which is currently not in existence.
4. Male students also require this focussed careers advice, but it should continue to be balanced with a range of other careers experiences, including visitors, workshops and careers fairs.
5. All students have a poor perception of the quality of physics education that they have observed – steps need to be taken to reduce the usage of non-subject specialists at formative points within the educational pathway to reduce the numbers shying away from physical sciences career pathways.

When the student teachers were questioned about their viewpoint on these issues, they also echoed the concerns about the abstract nature of many of the secondary STEM level syllabus' and the lack of obvious relevance of the material to future career paths. This reinforced the need for well-structured careers advice in support of this, but many felt that the students were focussing on subject syllabus for selection rather than taking any long term view on potential career opportunities (linked back to the issues with the number of students now moving away from the traditional balanced approach to STEM education). This will require an increasing level of intervention from the careers support staff to encourage students to take a longer viewpoint on the consequences of the choices that they make as early on as GCSE. Following on from the trend in selection of individual sciences at GCSE level and the future negative impact on A-Level (and university level) STEM subject uptake – the teachers highlighted their experience with many of the science subjects being mutually supporting, and in many instances, the cross-disciplinary learning processes can assist in achievement in each of the individual streams. By limiting focus to one or two of the sciences, the students loose the benefit of the multiple viewpoints (biological, chemical and physical) on common problems, and with this will often have reduced understanding of the fundamental concepts and often resulting in a lack of appreciation of the real world context. A final note of concern from the educators' perspective was the increasing level of assessment which is being introduced into the educational process at an ever earlier point. There was a feeling that subjects were becoming increasingly assessment focussed, with little opportunity left for meaningful exercises to be introduced into the curriculum purely for exploratory learning and linking theory to real life. Particularly in physics, it was noted that many of the practicals at GCSE and A-Level were often abstract and unrelated to the core syllabus. Given the desire of the students to have a better appreciation of the relevance of subjects to careers, this balance needs to be re-examined.

4. CONCLUSIONS

There is little doubt that action needs to be taken with regards the declining numbers entering into STEM careers - while the overall student population undertaking first degrees has been growing over the last ten years, there has been a reduction in the percentage of that population entering into engineering and technology routes. In comparison to the rest of the UK, first degree enrollments in NI in engineering are at 80% of the UK average, and the number of graduations is showing a relative decline of approximately 1% per year. However, it is clear that this is arising from problems much earlier in the educational process, and can be identified as early on as GCSE selection, where some of the key subjects (such as physics) are rapidly on the decline. The core message which has been obtained from students surveyed in QUB and reinforced by interviews with teachers is that students in Northern Ireland are not receiving an adequate level of careers advice and this needs to be re-dressed to attempt to reverse this trend. By having a stronger STEM careers pathway inbuilt into the educational structure, students will have a better appreciation of the long term job opportunities, increasing the potential for growth in the STEM sector at a time when it is needed.

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GRADUATING PROFESSIONAL ENGINEERS AND MANAGEMENT SKILLS – ARE THEY ADEQUATE FOR THE WORKPLACE?

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***Abstract**: This paper considers the notion that for the majority of engineers, the development of managerial skills will be essential and cannot be 'picked up on the job'. Engineers increasingly need to understand the interactions between design, quality, sustainability product planning, organisation, management of people, team work and finance. This paper considers the need to develop managerial skills and will discuss the development of a survey to be carried out in an Australian context. The survey will cover a range of firms and governmental bodies that employ graduate engineers. The questions will cover a wide range of non-engineering skills that could be expected of engineers within the first five years of the commencement of their careers.*

The two disciplines, Engineering and Management have enjoyed a rather difficult relationship for some time. Each needs the other because complex engineering tasks cannot be carried out in an increasingly challenging business environment without an integrated management focus. Engineers are finding they need to take on more complex tasks which include very significant managerial issues. Most engineering faculties have attempted to teach managerial skills in their engineering curricula. However, management education has often been viewed as secondary to technical skills and hence does not encompass the integrated range of skills needed. This has not motivated students to become interested in and committed to the management aspects of their future profession with the result that management education for engineers remains an enigma. This paper considers some of the contemporary literature on teaching management to engineers. Some ideas are discussed outlining possible research which will be carried out and reported by the authors, aimed at documenting current shortcomings with a view to developing a more effective future strategy for engineering management education.

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1. INTRODUCTION

In the current economic climate graduate engineers are finding they are required to undertake an increasing range of complex tasks that require a challenging range of skills which include very significant professional managerial issues. Typical tasks required include some or all of the following:

Strategic focus, financial management and control, quality management, human resource and stakeholder management and industrial relations.

More and more in recent times, due to the nature of their technical knowledge and education, engineers are also finding themselves leading the crucial thrust towards sustainable engineering business. However, university education has tended to rely on the knowledge of engineering technology experts who have little inclination towards engineering business and the resulting commercial challenges of the 21st Century. University engineering education can no longer be described as 'basically scientific and technical in nature' and must be integrated with a knowledge base associated with Commerce and Business. Most engineering faculties have attempted to teach managerial skills in their engineering curricula. However, these have often been approached as a secondary issue and, consequently, as a ‘bolt-on’ to the technical skills being imparted and hence they do not fully encompass an integrated range of management issues and skills needed. This approach has not motivated students to become interested in and committed to the management aspects of their future profession. Consequently, problematical teaching of management areas is an issue for many Faculties of Engineering. Employer dissatisfaction has also appeared because new graduates are not orientated to meet engineering management challenges and consequently they cannot immediately contribute to business outcomes in many engineering and industrial organisations.

Engineers tend to be uncomfortable with the management aspects of their profession because engineering is considered a rigorous, scientific discipline whereas management is a social science discipline, taught by case studies, anecdote and other non quantifiable methods. Many students chose engineering because they do not wish to study in that way, which leads to further compounding of the problems. This paper attempts to describe and review the professional managerial skills that will be needed by graduate engineers to allow them to perform to a satisfactory level within the current multiskilled work environment and better meet the needs of employers. The history of management skill identification is reviewed from the work of Katz (1955) through to the present and a list of the identified managerial skills needed of a manager is presented. This list is then modified to highlight those which the authors suggest are relevant to the training of a fully rounded and competent graduate engineer.

2. PROFESSIONAL ENGINEERING MANAGEMENT

For the purpose of this research, professional engineering management is defined as the skill of managing both engineers and other non-engineering employees in a practical, commercial and non-commercial environment. The additional skills that will be needed for engineers to successfully manage in this environment will include human resources, financial, operational, marketing and others.

The term Professional Management Skills for Engineers (PMSE) is suggested as a term to describe the skills believed to be necessary for both undergraduates and postgraduates to participate fully in the running of an organisation and be fully conversant with the skills and attributes to successfully manage disparate groups of both professional and non-professional employees in a timely and efficient manner.

This topic has been of relevance for some decades. In 1984 the following comment was made by Lord Flowers, FRS, Rector, Imperial College of Science and Technology, London at the Second World Conference on Continuing Engineering Education, Paris, France in 1983 (cited by Martinec (1984)).

> "*For the majority of engineers, the development of managerial skills will be essential and cannot be picked up on the job. The engineer will, in general, increasingly need to understand the interaction of design with quality control, commercial and product planning, organisation and finances, and will need to develop the managerial skill of financial control, industrial relations and Marketing."*

Research has identified that since this time, PMSE has been considered an integral part of the skills and attributes that a graduate engineer should possess. This comment is backed by a large body of scholarly literature and reference is made to the following authors - Aldridge et al (1990), Brisk (1997), Carmichael & Gibson (2001), Childs & Gibson (2007, 2009), Director (1996), Jenson (2000), Kocaoglu (1984), (1994), Kocaoglu et al (2003), Martinec (1984), McCahon and Lavelle (1998), Nambisan and Wilemon (2003),Wilkinson (2002) and others.

To date little has been discovered on the needs and perceptions of employers as to the skills and attributes they perceive as being either essential or desirable for graduate engineers to possess and the resulting influence this has on business performance. Literature discovered to date covering this aspect and the limited scholarly research on the attributes and skills required by an engineer generally, is mostly discipline based and is covered by a small range of authors. Some authors have attempted to define these general skills without a particular reference to managerial skills. The generalised list of authors is as follows – Chisholm (1999), Editorial (2004), Edum and Fotwe (2000), Gibson and Carmichael (2001), Holfield and Thomas (1999), Plonka et al (1994), Rifkin et al (1999) and others.

Of other authors, Liyanage (2001), Gibson & Carmichael (2001) and Thilmany (2004) have all reviewed the needs and dimensions of postgraduate engineering courses and have highlighted the need for engineers to study and absorb 'management concepts'.

Gibson and Carmichael (2001) comment that:

> *Leading firms are working with universities to develop innovative ways to progress and develop their staff throughout their careers. The divide between working and learning is becoming increasingly blurred. The global dimension adds further challenges that will probably result in strategic alliances and networking capabilities that allow even greater degrees of customisation and just-in-time delivery. There are enormous challenges for engineering and technology schools in how they develop future profiles of their academic staff."*

Of recent literature Patil & Codnel (2007) have found that engineers now require global competencies such as an awareness of global political and social issues, and knowledge of cross cultural and multicultural issue. They also need to understand international business, the local and international economy and the world market. These comments were also commented on by Nair & Patil (2009). Trevelyan (2008) comments on the way current engineering education is based on engineering practice which covers technical problem solving and design and this represents a misalignment between engineering education and engineering requirements in real world situations. It does not take into account the very important factor that engineers spend time interacting with people.

And Wei (2005) in reviewing current education commented:

> *' It has always been a point of tension to achieve both breadth and depth in 4 years, and the engineering accreditation process has accepted the notion that between one-eighth and one-quarter of the engineering curriculum should be devoted to humanities and the social sciences'.*

Wei continues to review the changes in both the developed and developing world in which the former is moving rapidly to become a service economy and then onto a knowledge economy, whilst the developing countries will continue to need traditional engineers for some time. However, it is believed that this time frame is shortening rapidly. This short review of the development of engineering management education has shown that this field is an area of concern to engineering educators. This area of concern questions whether it is possible to blend a hard fact driven education, such as engineering, with a discipline that seeks optimal solutions as opposed to an optimum solution.

3. PROFESSIONAL MANAGEMENT SKILLS FOR ENGINEERS (PMSE)

In the management area of academia the art of management was generally defined in the 1955 paper by R.L. Katz published in the Harvard Business Review (HBR). His understandings of the skills of an effective administrator (manager) were listed as follows (with the authors' comments in parenthesis):

> *Technical – need sufficient technical skill to accomplish the mechanics of a particular job for which he is responsible (*these skills would presumably be part of an undergraduate degree curriculum)
>
> *Human – (have) human skill in working with others to be an effective group member and to be able to build cooperative effort within the team he leads.* (generally not taught as an integral part of an undergraduate degree)
>
> *Conceptual – (have) sufficient conceptual skills to recognize the interrelationships of the various factors involved in his situation which will lead him to take that action which achieves the maximum good for the total organisation.* (generally not taught as an integral part of an undergraduate degree) *(Katz, 1955 p42)*

This seminal paper was reprinted as a HBR Classic in 1974 with the additional comment that all managers, whatever their level will need some skills in all these three areas. In 1986 HBR again reprinted sections of the paper and it was revisited by Peterson & Fleet (2004) who expanded and modified some elements but still stayed essentially true to Katz' original statements. In their review, Peterson & Fleet (2004) also identified an additional seven skills listed in the texts alongside Katz's three skills. Thus, from this series of papers we can postulate a summarised series of ten management skills that it is felt graduate engineers may need to possess. These ten attribute skills are as listed here and encapsulate current thoughts on the skills that a manager needs to be fully effective. These are - Technical, Analytic, Decision making, Human, Communication, Interpersonal, Conceptual, Diagnostic, Flexible, and Administrative. These correlate relatively well with those 'softer skills' identified by Robinson et al (2005).

These attributes/skills were used by the authors of this paper in their research into the development of a questionnaire to assess the current status and success of engineering management education that will be sent to Australian industrial and commercial engineering organisations to determine what skills they would desire from their newly graduated engineers. This list outlines the areas that should be considered when evaluating what management skills a graduate engineer should possess. However it does not mention financial concept skills, quality management skills, or marketing.

The basis of the research of the authors of this paper is to ascertain what skills employers believe they want their engineers to possess, particularly for those employers who expect their engineering employees to become professional managers (at some stage in their career). The skill set will be potentially different for different engineering disciplines as well as for different phases of the economic cycle.

A review of the literature did not identify any areas of agreement of what management attributes a graduate engineer should possess. A major paper reviewed by Robinson et al (2005) surveyed design engineers in the UK on what skills they should possess to competently carry out their tasks. They indicated six groupings into which the authors categorised the skill sets identified. This survey was biased towards an engineering perspective but surprisingly identified many of the softer skills of management as put forward by Katz (1955).

Research was carried out by Peterson & Peterson (2004) who researched the managerial needs of a mid-level management position within a USA government organisation. This research involved a series of surveys on management needs. In the first survey they requested 23 senior managers to comment on three aspects of management based on Katz’ (1955) listing of technical, human, and conceptual, and required them to estimate the time spent within their positions on these three aspects.

Interestingly, in this survey, human skills ranked first with technical skills ranking last. The research continued with the senior managers asked to observe critical incidents, both those that were successful and those that were unsuccessfully resolved. They were asked to identify those skill categories which were used in the incident observed.

Again the ranking was the same as in the first survey and confirms Katz’ original contention that managers need not only technical skills but also those of the ‘softer’’ variety.

The recipients of the survey were then requested to use a seven point Likert scale to rate how important each skill was in the opinion of the respondent. In addition each respondent was asked to rate their own capability.

The top three skills identified as essential were - acting consistently, is truthful and builds trust, all HR attributes. The study, although designed to assess skills for a particular position highlights the need for managers, of all types, to attain a certain set of (professional management) skills to be fully successful in a managerial position.

The surprising omission in all papers reviewed from the engineering side was financial skills, but this could be due to the focus of the study being on engineers and the group chosen for the study. More recently, it has also become necessary to add the need for new engineers to appreciate the need to manage engineering in an environmentally sustainable way. This adds further complexity to the engineering management teaching task.

It is proposed that in this research the authors of this paper will blend the work of Robinson et al with the work of Katz (1955 etc) and with later authors, Peterson & Fleet (2004). The work of Katz (1955 etc) and others is included as it reviews management skills from the 'commerce' side of an organisation. However, managing sustainability must also be included as an essential future dimension for engineers to attain.

Peterson & Fleet (2004) have developed a list of these skills together with an explanation of what is required of each skill. Their definitions were used to develop a list of suggested attributes which graduate engineers should possess. The skill listed as technical has not been included as it is expected that this skill would have formed part of the engineering curriculum.

Decision Making Ability - *To be able to assess and decide between competing solutions to a particular problem. This skill will have been taught in relation to their technical skills but not necessarily in relation to the decision that a manager needs to make.*

Human Skills - *To be able to work with, communicate, negotiate and relate to others both within the organisation as well as outside the organisation. Also be able to teach others, work in groups and with individuals at various levels of management. Resolve conflicts.*

Communication -*Be able to send and receive information, thoughts and feelings, which create common understanding and meaning.*

Interpersonal - *Ability to develop and maintain a trusting and open relationship with superiors, subordinates, peers and external personnel to facilitate the free exchange of information and provide a productive work setting.*

Conceptual - *Ability to see the organisation as a whole and to solve problems from a systematic point of view.*

Diagnostic - *Ability to determine the probable cause(s) of a problem from examining the symptoms and which are observed by the manager.*

Flexible - *Ability to deal with ambiguous and complex situations and rapidly changing demands.*

Administrative - *Ability to follow policies and procedures, process paper work in an orderly manner and manage expenditures within the limits set by budgets.*

Other skills that should be included in the discussion are those mentioned by Lord Flowers –

"- quality control, commercial and product planning, organisation and finances, and will need to develop the managerial skill of financial control, industrial relations and marketing."

Lord Flowers (cited by Martinec (1984).

The above list of attributes will be used as the basis of the questionnaire which will be issued early in 2010 to a range of Australian organisations with results expected to be available by mid – year 2010. The respondents will also be questioned as to whether they feel these skills should be taught as part of a University engineering curriculum or as part of a normal 'on the job' training by the employing entity. The survey (of 23 questions) sample will be based on the Australian Bureau of Statistics business listings (ANZSIC) and will encompass approximately 18,000 firms across the following six (6) segments – consulting, construction, manufacturing, mining, public services & utilities and transport. Each group will also be subdivided into small, medium and large organisations based on the number of employees. The sample size will be approximately 800 – 900 potential respondents and will be chosen at random and proportionally from the eighteen (18) sub groups. The sample will be distributed at the end of May 2010 with responses expected during June. In addition a questionnaire has been prepared for submission to all Deans of Engineering faculties in Australia. This survey will be submitted through the Deans Council.

The overall goal is to assess the needs of Australian employers of graduate engineers and the skills and attributes that they feel are needed in today's business environment and to asses the way in which Engineering Faculties are incorporating these needs into their engineering curriculum.

4. CONCLUSION

The authors of this paper have developed a questionnaire to be tested within the Australian context to ascertain the viewpoint of the employers of engineers (of all disciplines) as to whether engineers require knowledge of management skills upon graduation. It is the authors' belief that this is correct.

Based upon the authors reviewed thus far it appears there are problems with professional engineering management education and there appears to be no firm decision as to whether this skill is needed. The varied topics to be taught in professional management education across the papers reviewed and what constitutes this discipline require clarification as follows:

should engineers be taught professional management concepts which subjects will constitute this discipline

where this discipline will be taught, (e.g. in the engineering faculty or in the commerce or business school faculties)

who will teach it and at what level (undergraduate or postgraduate) will the courses be offered

Underlying this dilemma is the question of how can engineers be trained to satisfy tomorrow's requirements. Amongst a range of skills needed. Sustainability is clearly becoming a further management challenge for engineers. What skills will these engineers need, what skills will academics need and how and by whom will these various skills be taught? The aim of the authors of this paper is to answer these questions and propose a list of skills that can be put forward as those skills required by engineers and employers to allow the graduate engineer to seamlessly integrate into the organisation and be ready to assist in the attainment of the goals and objectives of the parent organisation.

To assess the attitudes of Australian employers a questionnaire has been developed that will be submitted to a suitable range of Australian organisations to evaluate the needs of employers and close the perceived gap in the relevant literature. The survey will particularly investigate the potential for employers to partner with universities in helping to develop and participate in curricula. Results of this survey are expected to be available by mid-year 2010.

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SUSTAINABILITY: WORDS OR DO WE REALLY TEACH THE ENGINEERS EFFECTIVELY?

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Abstract: Sustainability is an important concept of engineering education and methods of embedding it into curriculum are continuously sought. The Institution of Chemical Engineers 'sees sustainable development as the most significant issue facing society today' (IChemE) and places great emphasis upon the embedded learning of sustainability within the curriculum, as evidenced in their new accreditation guidelines. Newcastle University was amongst the first to gain funding from RAE for a Visiting Professor in Principles of Design for a Sustainable Environment. This led to the development of a number of case studies used in the education of engineers.

This contribution describes the efforts at CEAM to embed sustainability into curriculum from week 1 of chemical engineering curriculum. These include a week long module of introduction to chemical engineering in the first year, a number of industrially relevant case studies within Enquiry Based Learning (EBL) that have a great societal impact. Details of the transition towards EBL, the case studies on fuel cell effectiveness and sustainable plant design are provided. Emphasis is placed on the methods of assessment of student learning as well as methods of evaluating the effectiveness of delivery using case study approach. Student focus groups and diamond ranking confirmed that students perceive the case studies as very important and prefer developing their skills of sustainable design in realistic setting.

Keywords; sustainability in chemical engineering curriculum, Enquiry Based Learning, assessment.

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1. INTRODUCTION

1.1 Sustainability in higher education

Limited resources on Earth and the resulting economic, social and environmental challenges facing society are prompting extensive debates about the role of higher education in developing appropriate attitudes of students towards these issues**.** The Department for Innovation, Universities and Skills (DIUS) identified sustainable development as an important part of HE:

> "Sustainable development – meeting the needs of the present without compromising the ability of future generations to meet their own needs – is a defining challenge of the twenty-first century. If the nation is to play its full part in challenging global poverty and combating environmental problems like climate change it is imperative that everyone in this country develops the skills of sustainable living and working. That means placing sustainable development at the heart of skills provision, ensuring that it is a fundamental goal of our economic and social progress." (DIUS 2007, section 1.20)

Professional institutions, such as the Royal Academy of Engineering and the Institution of Chemical Engineers, have introduced a number of initiatives to encourage the integration of sustainability into HE as well as its industrial application. This is evidenced, for example, by the requirement placed on the academic institutions seeking accreditation of their courses by IChemE to demonstrate sufficient provision of embedded teaching of SHE, sustainability and ethics (IChemE, 2009) or by the provision of a sustainability metrics tool to help industry assess the impact of their operations (IChemE) and the provision of guiding principles on engineering for sustainable development (RAE, 2005).

1.2 Chemical engineering curriculum at Newcastle University

Nationally chemical engineering curriculum has traditionally been delivered in a relatively conservative manner. The changes in the world-wide market as well as societal challenges we are facing require a review of not only the content, but also the mode of delivery of the fundamental knowledge and skills in this area. Curriculum review process was initialised at CEAM, Newcastle University in 2007 and involved detailed research into effective methods of engineering curriculum delivery enabling the development of employability skills – problem solving, team working, data analysis, etc. Whilst the School benefits from the University Graduate Skills initiative, providing students' opportunity to develop 'transferable skills', feedback from potential employers stressed the importance of developing critical skills in subject context.

The requirement for the Universities to ensure that 'they are preparing their students for today's competitive job market' is widely recognised (e.g. Knight and Yorke, 2003), but so is the difficulty of achieving this in academic environment (Cranmer, 2006), in particular at the current, very challenging economic climate (Rae, 2008). Emphasis on testing at earlier stages of education led to the 'loss' of important employability skills and thus CEAM decided to strengthen this aspect in their ongoing curriculum review. Enquiry based learning, centred on students working in small groups and solving of industrially relevant problems provides an opportunity to reinforce the subject knowledge and develop important skills.

1.3 Progressive development of sustainability theme through the curriculum

Students are introduced to the concept of Sustainability by a Royal Academy of Engineering Visiting Professor in Principles of Design for a Sustainable Environment. This occurs in their first week in the School. The one week special programme introduces students to the fundamentals of chemical engineering and allows them to consider the necessity of covering particular subject areas of chemical engineering within the curriculum, based on a realistic, but simple design problem. The students are presented with the design problem and specific tasks to be addressed on the first day of teaching. Subsequent contact sessions provide the necessary background knowledge in mass and energy balances, fluid flow, heat transfer and sustainability in order to solve the tasks. Students work in groups of 5-7 and have a number of tutorial sessions timetabled during the first week, when academics provide ‘consultation’ to the groups on various aspects, as required. Two weeks later, students present their solutions to academic staff in a 30 min interview session (Figure 1).

Figure 1 Small group presentation of the design task wet in week 1 in Stage 1.

A more detailed introduction to sustainability topics, such as global warming, ozone depletion, toxic emissions, poor air quality, water shortages and water pollution, acid rain, persistent organic pollutants, depletion of natural resources, loss of biodiversity, contaminated land, ecological principles, natural cycles, eco and carbon footprinting is provided within a compulsory module on Principles of Chemical Engineering. This module also introduces the role of an engineer in sustainable development, the issues of responsible care as well as issues of risk, liability and corporate manslaughter from the legal perspective. The relevant legislation framework and fundamentals of inherent process safety, COSHH and COMAH regulations, consequence of unsafe design and an examination of the issues surrounding the balance of cost and safety are covered in this module.

In 2009 a new case study on alternative energy sources was introduced to encourage students to use fundamental scientific principles acquired during chemistry and thermodynamics lectures to understand the working principles of both batteries and fuel cells and to be able to make calculations of cell voltages and cell efficiencies. The task, ‘Fuelling a manned mission to Mars’, inspires students to investigate effective energy sources (for example direct methanol, molten carbonate, phosphoric acid, alkaline and proton exchange fuel cells) and work in teams to devise the most efficient solution. Students have a series of timetabled group work sessions, including laboratory practicals, during which they can investigate the efficiency of certain types of fuel cells. The outcome of this case study is a group oral presentation and a group report. Peer marking is also used to achieve fair distribution of marks.

In Stage 2 the topic of responsibility and regulations is further developed in the Safety and Engineering Practice module. This module deals with SEVESO I and II Directives, risk management and environment, REACH, codes of practice and environmental law, risk hierarchy (i.e. eliminate, substitute, contain, protect workforce), emergency planning, protective equipment, training and management issues. In a workshop setting students are encouraged to think about risk and risk communication. This is based around a typical chemical plant and students evaluate the potential risks, who the stakeholders are, what they would need to be told and how to communicate effectively. Video footage and case studies of previous key industrial safety incidents illustrate Safety, Health and Environment & Loss Prevention principles. Risk and safety tools, including Hazard Operability (HAZOP), Hazard Analysis (HAZAN), As Low As Reasonably Practical (ALARP), Fatal Accident Rates (FAR) and Fault tree analysis provide the students with necessary technical knowledge for assessment of the impact of the planned operation. In addition SHE and sustainability topics are addressed in the subject specific modules, where these issues are emphasised in design approaches for unit operations, such as separation and reactor design.

In Stage 3 students are exposed to examples of clean technology research and its applications across a breadth of areas of chemical and materials engineering. The idea is to highlight the range of applications and sustainability of the concepts, (i.e. consider social, economic and environmental aspects), approaches and barriers to the implementation of clean technologies. The sustainability learning outcomes are brought together in the major group design project. Here the three components of sustainability - environmental responsibility, economic return and social development – represent an integral part of the design of the plant to satisfy given specifications. A significant proportion of the assessment of the design project is dedicated to these issues and students are required to critically address them. The final presentation of the design solution to the industrial panel specifically includes the assessment of sustainability of the design and the panel members include the RAE Visiting Professor in Principles of Design for a Sustainable Environment and practicing engineers with sustainability responsibility within their companies. The presentations are usually highly praised by the panel and indicate a high level of knowledge and skills in this area that the students gained over the three years of their studies.

In Stage 4 (MEng programme) the sustainability theme is further developed in the Enhanced design module and a range of optional modules specialising in Sustainable processing, energy and materials technology, Sustainable design and manufacture or Sustainable industry. These modules also build upon and utilise material produced from the RAE programme and include concepts such as Carbon footprinting, Life Cycle Assessment, Product Stewardship and Producer Responsibility delivered in a highly participative way. For example, students are divided into groups and they are asked to prepare and LCA for a given project, for example assessing a proposed onshore wind farm (MiddleMoor near Alnwick) or assessing a proposed gasifier to treat municipal solid waste in Newcastle upon Tyne. Half of the group is using the LCA approach to justify the case FOR and the other half AGAINST. The evidence and conclusions are presented in a group oral presentation together with social and economic issues. Students are encouraged to make key assumptions concerning life expectancy, location, sourcing of materials, data source and quality, recycling etc. If the LCA initiation stage is excessively skewed to suit the ‘for / against’ purpose, it would be thrown out by a peer review panel.

2. METHODOLOGY

2.1. Focus groups

Two focus group sessions have been organised. The first group consisted of 14 Stage 3 and Stage 4 students working in pairs and used diamond ranking (Woolner et al. 2010) to answer the following question:

1) What modes of delivery promote deep learning and professional skill development?

The outcomes of the diamond ranking were used as a basic structure for the following semi-structured interviews with 16 Stage 3 and Stage 4 students. In addition the results of an industrial focus group organised at an earlier stage, consisting of 9 representatives of potential employers, were used as discussion points to compare the views of students and those of employers.

The second focus group consisted of 9 Stage 1 students currently undertaking the EBL curriculum. These students participated in a semi-structured interview during which their views on the effectiveness of case study based EBL curriculum were sought. The focus group was facilitated by a researcher external to the school and in complete anonymity, to encourage students to express their views without reservations. The transcript of the session was then provided to the author and is discussed in the results section.

2.2 ELLI questionnaire

The Effective Lifelong Learning Inventory (ELLI) was developed at the University of Bristol, in a project funded by the Lifelong Learning Foundation (Deakin Crick and Yu, 2008). In ELLI seven dimensions of learning power are defined as:

- *changing and learning* (C&L) - a sense of oneself as someone who learns and changes over time; the opposite is being ‘stuck and static’
- *critical curiosity* (CC) – an orientation to want to ‘get beneath the surface’; the opposite is being ‘passive’
- *meaning making* (MM) – making connections and seeing that learning ‘matters to me’; the opposite is simply ‘accumulating data’
- *creativity* (CT)– risk-taking, playfulness, imagination and intuition; the opposite is being ‘rule-bound’
- *resilience* (RS) – the orientation to persevere in the development of one’s own learning power and relish challenge; the opposite is being ‘fragile and dependent’
- *strategic awareness* (SA) – being aware of one’s thoughts, feelings and actions as a learner and able to use that awareness to plan and manage learning processes; the opposite is being ‘robotic’
- *learning relationships* (LR), or interdependence – learning with and from others and also being able to learn alone; the opposite is either being ‘isolated’ or ‘over-dependent’

This method has been used in establishing links between the disposition of students to learn and the change in the mode of curriculum delivery towards Enquiry Based Learning. The new enquiry based curriculum delivery was implemented from September 2009 in Stage 1. ELLI questionnaire was administered to 72 Stage 1 students, following this method of delivery and 47 Stage 2 students, who completed Stage 1 curriculum without the benefit of the case study based EBL. The initial analysis of learning power provides a base value before and after intervention for Stage 1 and comparative values for the ‘control’ Stage 2 group. The ELLI questionnaire will be administered to the same students again in May 2010 to provide a comparison reflecting the impact of the EBL. The ELLI scores will also be compared to the academic performance of students to note any correlations. This analysis will only be possible at the end of the academic year.

3. RESULTS AND DISCUSSION

3.1. Focus groups

Students in the first focus group felt that practical skills and relevant subject knowledge were most important in promoting deep learning and professional skill development (Fig 2 with very detailed comments). It is thus not surprising that they almost unanimously identified industrial case studies solved in small groups, linking several modules and labs together, as the most effective method of achieving this and placed large lectures with lots of information delivered at the bottom of the diamond. Whilst the current delivery is in fact almost the opposite, the students themselves identify the need to practice professional skills hands-on with real life problems. This opinion was also voiced by the industrial focus group and clearly supports the move towards EBL case study based delivery.

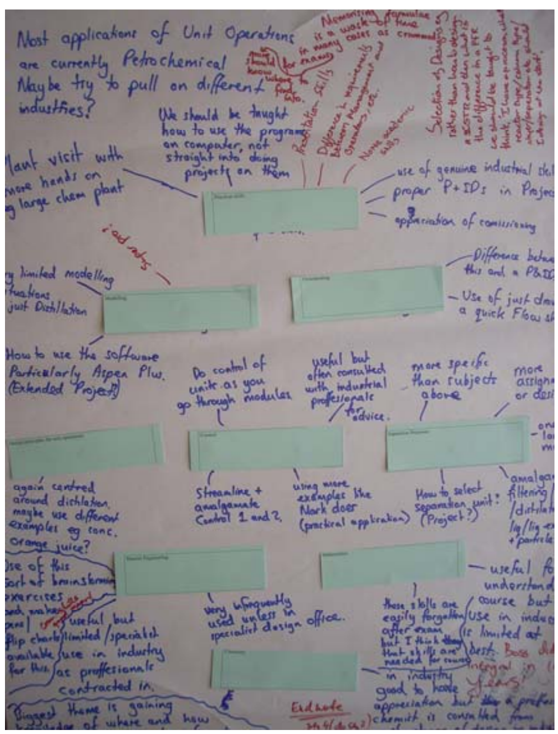


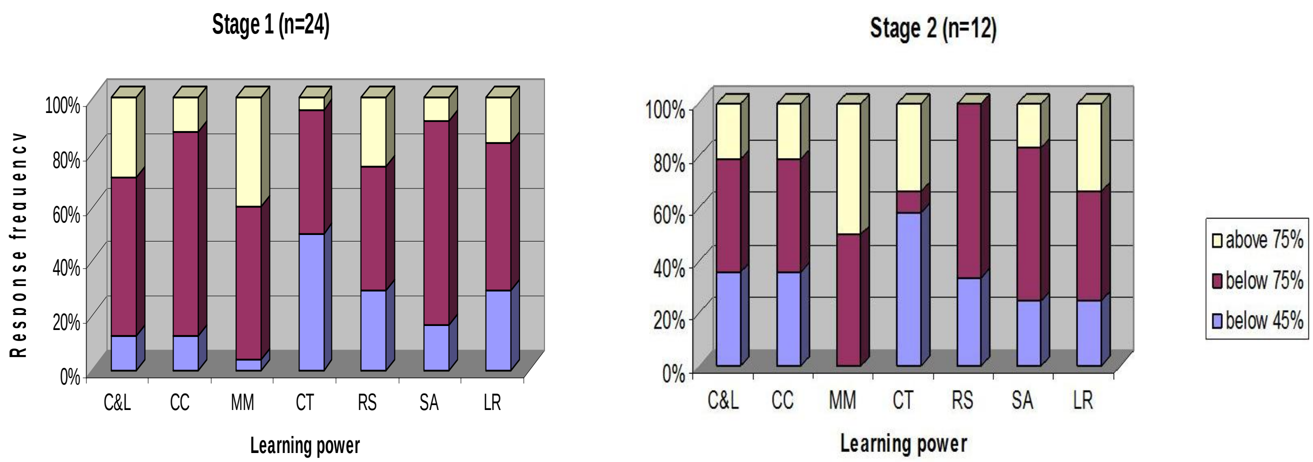
Figure 2 Diamond ranking representing students views of chemical engineering curriculum and its effective delivery

Interestingly, the students commented on subject areas they would like to see strengthened in the chemical engineering curriculum and amongst areas mentioned was deeper technical knowledge of alternative energy source, including nuclear energy. This demonstrates the high level of sustainability awareness of students.

Stage 1 students commented generally positively on the case studies during their focus group. One student said that it was 'quite good to apply what we have learned to the actual real world and industry but some of them are quite hard, throws you in at the deep end…. but I guess that is the point.' Generally the participants of this focus group found working in groups to be a positive experience. The negative aspects which were commented upon by many of this group were that there could be an element of unfairness if some members of the group did not participate fully. This is a common concern amongst students of all stages and the School addresses this issue in a number of ways, including peer assessment of individual contribution of each group member or using individual reflective reports to moderate the group mark attributed to each group member.

3.2 ELLI questionnaire

At this stage only the baseline results of ELLI questionnaire are available. The comparison will become available only after the questionnaire is administered to the students again in May 2010. Figure 3 summarises the mean responses of students in each category of learning power in Stage 1 (Figure 3a) and in Stage 2(Figure 3b). The colour scheme represents the percentage ELLI scores in each category for a given percentage of students from each cohort.



a b

Figure 3 Mean ELLI scores in each category of learning power (described in detail in section 2.2) for Stage 1 (a) and Stage 2 (b) students.

Although the response rate was relatively low in the initial stages (33.3% for Stage 1 and 25.5% for Stage 2), these responses are providing an interesting comparison of the learning power of this sample of each cohort. The most marked differences between the two cohorts are in meaning making (MM), creativity (CT) and resilience (RS). Interestingly the resilience of students in Stage 2 seems to be lower than those in Stage 1. Whilst somewhat surprising, as students in Stage 2 has been 'challenged' with engineering problems for a longer period than Stage 1, the introduction of highly subject specific and detailed topics in Stage 2 may influence the dependence of students in this stage upon the academics in achieving their learning goals. This also may explain the higher mean scores of Stage 2 students in the other two categories. It will be interesting to see if the case studies and EBL will increase the mean scores of Stage 1 students in these two categories by the end of the academic year.

4. FUTURE PLANS

Student focus groups provided valuable material for the continuing curriculum review process taking place at CEAM. Curriculum for Stages 3 and 4 is currently being revised with input from students, but also industrial focus groups and professional and quality assuring bodies. Full ELLI analysis of the first two cohorts of students will be available by the end of June 2010, although the intentions are to use this methodology for future investigations to gain understanding of long term impact of EBL upon student learning together with the assessment of sustainability attitudes of students.

5. ACKNOWLEDGEMENT

The contribution of all CEAM academic staff (in particular Dr S. Haile), visiting academics and industrialists as well as administrative staff contributing to the development and the delivery of sustainable education is gratefully acknowledged. Without the team effort, sustainability education would not be sustainable long term.

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PROBLEM BASED LEARNING IN MECHATRONICS

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Abstract: This paper briefly informs about the experience with teaching Mechatronics with the intensive use of real laboratory models. The HW and SW is based on Matlab/Simulink platform with extension to real-time applications. The difficult balancing between theory and students motivation is also mentioned.

Keywords; education; Mechatronics; educational models; Matlab/Simulink.

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1. INTRODUCTION

1.1 Motivation

The current civilization is based on technology, huge energy consumption and huge consumption of everything. Although many environmental and social problems we are facing now is based on negative impact of technology, it is widely believed, that further technical development can also help in solving those problems in the future.

Despite of this, the motivation of students in technical and engineering fields of study is more and more difficult in recent years. In this paper, the strategy of problem based education in mechatronics is described. The key concept of our Mechatronics laboratory is in the intensive use of educational models of real technical systems. The experience and gain acquired from the very basic and simple systems (such as DC motor with incremental encoders), more complicated MIMO systems and the real industrial problems are incomparable to the normal study approach.

1.1 Mechatronics

Mechatronics is typical interdisciplinary field of science and technology. Usually, mechatronics is defined as mixture (or optimistically: as synergistic combination) of mechanical engineering, electronics, computer sciences and control engineering to design the new product.

Most of power-producing and transportation systems consist of mechanical and electrical components and almost all new products require sophisticated computer control. Mechatronics is still relatively young field which allows the creation of integrated products with completely new functionality or can solve old problems using new approaches. Therefore it can be believed, that mechatronics can bring important contribution to the solution of challenging problems of the future.

Such wide spectrum of knowledge to be covered requires highly talented and motivated students but also offer enormous space for self-fulfilment and personal growth.

2. STRATEGY OF EDUCATION AT MECHATRONICS LABORATORY

The keystone of the problem-driven learning and teaching at Mechatronics laboratory is the use of real (physical) educational models. Based on this, the work in laboratory consist of following components:

- educational models
- Real-Time hardware and software for PC with Matlab/Simulink
- theory of modelling, control, signal processing etc.
- challenging team projects
- effective SW tools for teamwork and sharing of knowledge
- cooperation with industry (solution of practical demanding problems).

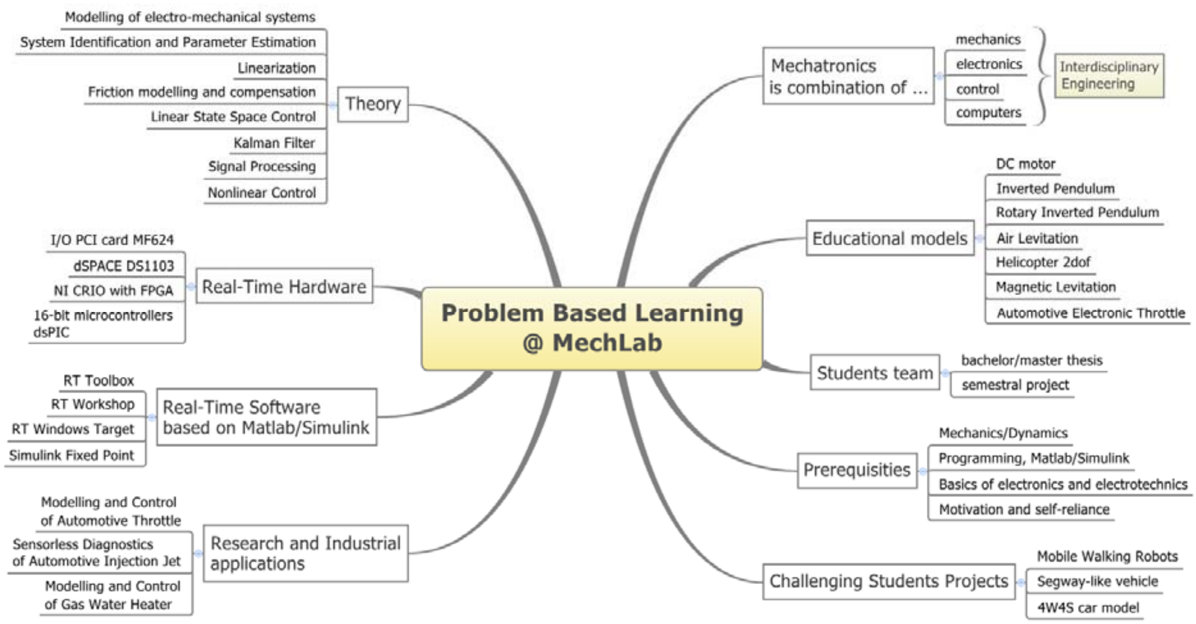

Figure 1 The map of PBL at MechLab.

1.1 Educational models

We use in MechLab these kinds of models:

- professional models
  - Magnetic levitation
  - Helicopter with two degrees of freedom
- models created by students as the result of bachelor/master thesis
  - Air levitation
  - Inverted pendulum
  - Rotary (Furuta) pendulum

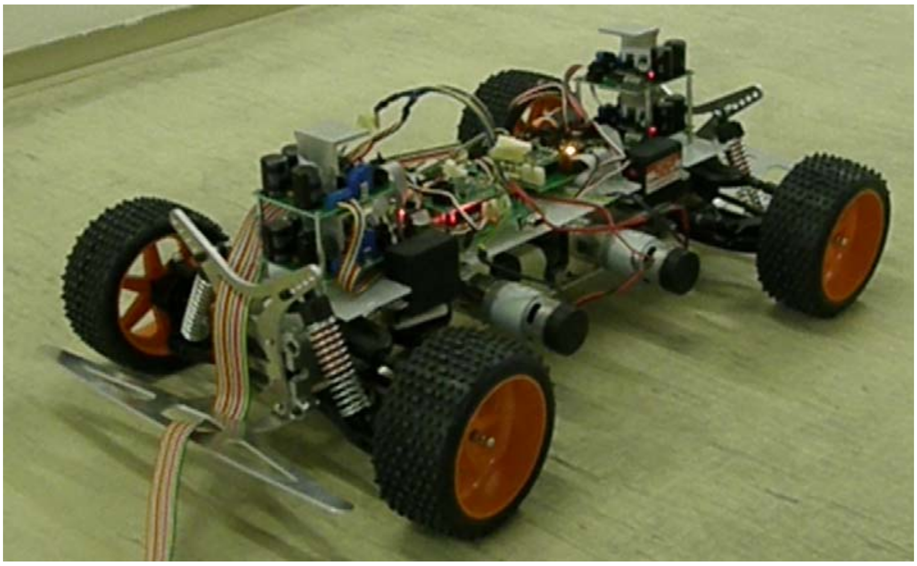

Figure 2 Students project: Experimental car with four steering and driven wheels.

- real automotive components
  - Electronic Throttle
  - Electrical Power Steering System
  - Solenoid Fuel Injection System
- complex team projects
  - Small experimental car with four steering and four driven wheels (Fig. 2)
  - Segway-like experimental platform

1.1 Software and hardware

Usually, many courses in Mechatronics uses Matlab/Simulink as the standard tool for modelling, offline simulation and control. We extend the application of Simulink into domain of Real-Time systems using special I/O hardware for standard PC and relevant software. This approach allows e.g. to teach the position control of DC motor with incremental encoder in 10 minutes, which is incomparable to classical (time consuming) employment of microcontrollers or DSP programmed in C.

1.1 Equations and other tools

The effective and motivated learning of complex theoretical topics must be driven by the actual problem. For example, our students group recently working on balancing wheel scooter is enough motivated to study Extended Kalman Filter for the signal fusion and processing.

Comprehensive theoretical knowledge is very important for the engineer although the trend is to use more “out of box” computer programs (generating colourful pictures) and much less pen and paper and equations.

1.1 Team projects

The teamwork is one of the fundamentals of problem-based learning. However, the justified scepticism is often expressed. The balanced compromise between the individual study and teamwork is the strategy in our laboratory. The team is the source of inspiration, place for dis-

cussions and interactive learning, but requirements, goals and responsibility must be clearly defined for each student separately.
In MechLab, most of our students work in team but all of them have individual bachelor/master thesis assignment.
The team spirit and knowledge exchange is also facilitated through the web portal with tools for project management and file sharing.

Figure 3 Student working on RobotX – project of mobile robot with hybrid undercarriage.

3. CONCLUSION

Our concept of the use of educational models as a means of motivation and problem-driven learning is successful. In previous years relatively high number of students went through the laboratory and finished with high-quality work and thesis. Most of students improved their results and increase motivation to study because of attractive and challenging projects. The only drawback of presented strategy is the enormous working load given on the teaching staff (besides lectures and exercises also the maintenance of laboratory models and equipment is required).

Finally, we would like to inform, that MechLab is interested in both pedagogical as well as scientific cooperation with similarly focused laboratories.

Acknowledgement: This paper was supported by project “Introduction of Problem Based Learning to Mechanical Engineering Curricula”, CZ.1.07/2.2.00/07.0406.

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Url: http://www.mechlab.cz

ASSESSING THE "SOFTER SKILLS" LEARNING OUTCOMES IN GROUP PROJECTS

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Abstract: The Product Design and Development and Mechanical Engineering degree programmes in the School of Mechanical and Aerospace Engineering at Queen's University Belfast (QUB) include major group Design Build and Test (DBT) projects in their 3rd and 4th years of study. These are advanced team projects which combine the technical and commercial elements typically found in industry. The students start with the identification of a problem and then develop a product through concept, product design specification, detailed design, prototyping and testing stages to finally produce plans for manufacture and commercial launch.
These yearlong projects seek to develop the students' skills and abilities across all phases of a product lifestyle and as such have a wide range of learning outcomes. Many of the learning outcomes are capable of being assessed through traditional means, such as written reports, but other "softer skills" such as time management and team working skills are less easily assessed in this way. Academic staff acting as supervisors of such projects cannot be with the students all of the time, particularly since they are often required to simultaneously supervise multiple projects as well as carry out research and perform other teaching and administrative roles. The potential to observe the operation of project groups over a long period of time and hence assess these "softer skills" is therefore reduced.
This paper will detail some of the methods used at Queen's to assist in the assessment of "softer skills" learning outcomes and evaluate their effectiveness in terms of time efficiency, accuracy and reliability

Keywords; personal and professional skills, "softer skills", group projects, assessment

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1. INTRODUCTION

The type of major group Design, Build and Test (DBT) projects carried out by 3rd Year Product Design and Development (PDD) and 4th year Mechanical Engineering undergraduate students at Queen's University Belfast is of a similar nature to the "capstone" projects carried out at many universities around the world. These generally seek to provide an authentic learning experience for students by including many elements which the students will face in professional practice, post graduation. The learning outcomes are broad and usually set at a high level of cognitive ability. In terms of taxonomy such as that described by Bloom (1956) the objective is to test the highest level of intellectual ability which involves evaluation and synthesis of a problem through to a viable solution. As well as applying technical knowledge and understanding the students are expected to develop a range of personal and professional skills, often referred to as “softer skills”. These may include how to plan and manage tasks in a timely manner, how to work effectively as a leader or member of a team, how to communicate effectively with team members and faculty supervisors and how to resolve conflicts. Unlike the cognitive domain these skills in the affective domain are not easily assessed by the methods traditionally used in engineering education. The situation can additionally be compounded by the fact that the tutors themselves do not have sufficient experience of or expertise in some of the skills, such as team working.

The requirement for these professional skills in addition to technical knowledge is recognised by a growing number of accreditation bodies such as the Institution of Mechanical Engineers (IMechE) who in the UK base their assessment on the Engineering Council’s UK-SPEC (Engineering Council, 2010) document. This specifies a standard for professional engineering competence including 2 sections (C and D) which relate specifically to “technical and commercial leadership” and “effective interpersonal skills”. Similarly the international CDIO initiative, of which the QUB School of Mechanical and Aerospace Engineering (SMAE) is a leading member, has identified this requirement. A series of stakeholder surveys undertaken by a number of the collaborating universities highlighted that these personal and professional skills are highly valued by employers and recognised by alumni as being every bit as important as technical knowledge in professional practice. Consequently the Syllabus developed by CDIO contains sections which deal with these requirements namely; Section 2 on Personal and Professional Skills and Attributes and Section 3 on Interpersonal Skills: Teamwork and Communication (Crawley et al, 2007).

CDIO Standard 5 specifically states that degree programmes should have an introductory course that incorporates DBT experiences followed by at least one further DBT exercise of a more advanced and demanding nature, usually the capstone project. This rationale has been extended on the PDD programme to include an additional half module (5 ECTS points) group project in first year and a full module (10 ECTS points) with 3 group DBT exercises in 2nd year. This has been done to allow a staged development of the required skills and attributes.

1.1 Some Relevant Literature

The psychologist Csikszentmihalyi (1990) describes flow as a state of consciousness in which people are more engaged with and get greater satisfaction from the activities in which they are involved. In an educational context this relates to deep learning rather than surface learning and assists the individual in their ability to progress through the stages of cognitive development. Csikszentmihalyi also contends that this state can be controlled by ordering the information that enters the consciousness. Often referred to as the “+1 principle”, this requires setting tasks of appropriate level, challenging but achievable and related to prior knowledge and skill levels. Often described as being between boredom, where no new learning occurs, and panic where survival strategies rather than deep learning dominate.

In the case of the DBT projects Bloom’s taxonomy of learning domains (Bloom, 1956) is used to guide the setting of learning outcomes for each year with appropriate progression (Hermon et al, 2009). Hence the students are able to build on their previous experiences of shorter group projects in the earlier years before being asked to tackle the capstone DBT project. This approach is aligned with the constructivism theory work of Vygotsky (1980) and the experiential learning cycle model of Kolb (1984) and means that graduating students are better prepared for professional practice by the repeated opportunities to improve their personal and professional skills in the context of their application to multiple DBT projects.

Student self and peer assessments have been shown by many to be at best unreliable as a measure of absolute and relative performance. Kruger and Dunning (1999) found that people tend to overestimate their own performance and that the least skilled in a domain are least able to assess their own and the ability of others in the same domain, largely it would seem due to their own inabilities. They also describe a common “above average effect” in which less able students regularly rate themselves significantly above the average of a group. The use of such student generated assessments needs to be done with the prior knowledge that it has limited absolute accuracy but that can provide valuable insights into student ability, by judging their ability to assess others, when compared to assessments made by a tutor of the same students.

1.2 Capstone Project Learning Outcomes

Stage 3 PDD and Stage 4 Mechanical Engineering students undertake a major (capstone) group project which accounts for 1/3 or 1/4 of their academic programme in the respective years. The learning outcomes are similar in both cases and can be summarised as follows:

To provide students with experience of working within a team on a realistic major project developing a product from the identification of a problem / customer need through concept development, product design specification, detailed design, prototyping and testing and finally to a plan for manufacture.

After successfully completing the project students are expected to be able to:

1. Apply knowledge and understanding of a specialist subject and related elements of professional product design practice.
2. Collate information, analyse and solve a technical problem.
3. Design or develop a system, component or process and recognise opportunities for improvements in a design.
4. Utilise appropriate laboratory equipment, computer software and instrumentation, in order to accomplish the objectives of a project.
5. Communicate effectively the results of a project in oral presentations and written reports.
6. Design and plan a project and manage the time involved to complete all tasks to the respective deadlines.
7. Work and learn independently and as a member of a project team.
8. Work and communicate effectively as a member of a project team.

The teams of typically between 4 and 6 students produce a number of deliverables during the 24 weeks of the project such as technical reports, working prototypes and oral presentations. These provide content which can be graded in relation to the product rather than the process and the collective output of the team rather than the individual. As such these deliverables are linked to and can be used effectively in the assessment of learning outcomes 1 to 5 but not for items 6 to 8 which relate to the personal and professional skills and attributes.

Biggs (1999) states the importance of appropriate teaching and learning activities being provided and that assessment methods are constructively aligned with these. The remainder of this paper will detail procedures being employed in an attempt effectively assess these “softer skill” learning outcomes (6 to 8) in the 3rd year group projects on the PDD degree.

2. ASSESSMENT

It should be noted that while conflict resolution is a desirable skill it is not included in the learning outcomes. We have chosen to avoid conflict where possible rather than engineer artificial scenarios. It is assumed that in any project there will be sufficient disagreement within the group that some experience of dealing with conflict will be gained. With this in mind the groups are constructed by the module coordinator with the objective of being balanced and harmonious.

2.1 Building "Super Groups" and Avoiding Dysfunctional Groups

In order that all students work in an environment which is conducive to learning some effort has been put into the formation of the groups for the capstone project. By the end of 2nd year the students will have worked on 7 DBT projects of between 3 and 12 weeks duration. In all these cases the groups will have been constructed by the tutor with the objective of creating teams of balanced ability and learning style preferences. At the end of 2nd year the students (typically 30 in a PDD cohort) should have worked with all members of their year on at least 1 project. At this stage they are asked to confidentially rank all the students in their cohort in terms of their preference as a partner for the capstone project in stage 3. The top students in terms of previous academic performance are seeded into the various groups and they get to work with their first preference choice, or highest preference not currently assigned to another group. The 2nd student in each group then gets their highest preference still available and so on. In general the students have tended to produce a preference rank which correlates reasonably well with the performance ranking but significantly there are a few notable exceptions each year. Some very able students are not seen by their peers as being desirable partners for group work while others of lesser ability are considered highly desirable as team members. These individuals are the ones whose data points lie furthest from the best fit line of the graph in Figure 1. The general correlation between performance and preference suggests that students are very aware of each other's skills and abilities and rank their choices accordingly .

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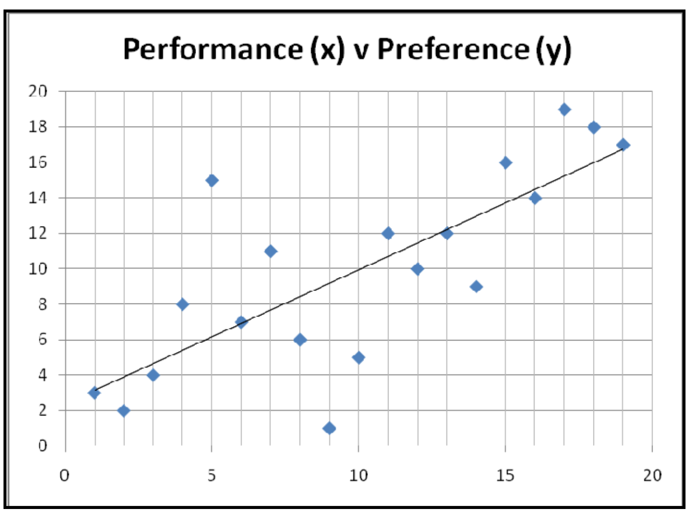

Figure 1 – 0910 Stage 2 PDD performance versus peer preference rankings

This information can then be used in discussions with individuals as part of a Personal Development Planning (PDP) process either with the module coordinator, project supervisor or personal tutor. The same data also indicates which students individuals absolutely do not want to work with as they will rank them last in their preferences. Hence individuals who are likely to fail to work effectively together can be kept apart. What is significant here is that this data tends to indicate something of the group dynamic within the cohort which is not easily observed by the academic staff. The students spend longer working with each other on these projects than it is possible for the faculty members to spend with each student and they are constantly making decisions and judgements about their peers in relation to how effective they are in their roles. The idea that the students form assessments of their peers that can be useful in helping faculty assess personal and professional skills has also been used in other areas of the assessment of these DBT projects.

2.2 Peer Assessment

Peer Assessment spreadsheets are used in all group projects in all years of study and are a mandatory requirement but do not contribute marks to the assessment. The confidential peer assessment works on a zero mean basis with each student scoring themselves and all other members of the group in each of fifteen categories, which are aligned with the deliverables and learning outcomes of the particular project. Each row must add to zero and justifying comments must be entered for any rows with a non-zero value in any cell. These comments provide useful evidence to support the supervisor's observations of the group and the structured format ensures that each student comments on the same aspects of the project which enables direct comparison across the group.

Guideline statements are provided describing the range of values between -2 and +2 which students can enter in each cell. 5 of the 15 categories typically relate specifically to personal and professional skills, e.g.:

- Effectively takes charge of tasks assigned
- Is fair and even in the treatment of other group members
- Produces work on time
- Willing to take on tasks
- Communicates clearly with other members of the team

In the capstone project students are required to complete a peer assessment at the end of the first semester, which is half way through the project. At the start of the second semester all students have an individual interview with their project supervisor(s) which includes a discussion of the collated peer assessments for each group. Student's comments remain confidential but a summary of the scores is fed back to each student as the basis of a discussion of their own performance and to provide a focus for areas which could be improved. This practice has proved particularly beneficial to the students and has been warmly received by them as positive and constructive feedback. The timing of the feedback provides the student with an opportunity to take corrective action and for the supervisors to focus the attention of their observations over the 2^{nd} semester on areas identified by the other students as being relatively weak. The students then complete a similar peer assessment at the end of the project which provides an opportunity to assess any improvement as observed by the other student members of the group. It is important that the benefit of the peer assessment is sold to the students from the start of the project so that honest and valuable information is gathered for the interim feedback interviews. The use of the same format of peer assessment in previous years has built a familiarity which ensures high quality data is provided. The submission deadlines for these peer assessments is always set to be after other major assessments so that it both encourages reflection and also doesn't interfere with the ability to make the deadline of the assessed elements.

2.3 Online Collaboration

Since 2008 online collaboration has been facilitated by setting up private forums using Google Groups. This free web based utility is a refinement of Usenet discussion groups which have been in use for many years. The module coordinator creates a new group and restricts membership by invitation only to the students and supervisors of the project. This provides the students with a shared space to upload files and a discussion forum to share information about relevant resources, reports and journal articles as well as somewhere to coordinate the scheduling of tasks. The students are sent an email when new content is added and the supervisors can read and contribute to the discussion threads as well as provide instant feedback by rating each post on a 1 to 5 star basis. The resource can be accessed anytime and from anywhere with internet access and complements the required face to face project review meetings which the students organise and run with their supervisors. The students are made aware from the outset that their contribution is graded on a weekly basis as a measure of their level of engagement in the project and of their level of professional practice. By signing up to receive digest emails the supervisors conveniently receive a transcript of all activity in the group which can be kept as a record.

Quality as well as quantity of contribution is both measured with guidelines provided on the scoring metric used by the supervisors. The highest marks are reserved for contributions which clearly demonstrate a responsibility for moving the project forward. Posts stating only the detail of work done by an individual on their assigned tasks receive only a pass level grade. Year 3 students are expected to make at least 4 contributions to the online forum per week, but should be doing this as part of the normal function of the project and are therefore not subjected to any additional assessment burden.

Fundamentally this facility enables the supervisors to obtain a view of how the group is operating. It can be used to ascertain who in the group is driving things forward, who can effectively communicate what they are doing and who can produce a concise summary of relevant technical information. The fact that it is ongoing for the full duration of the project removes the risk of inaccuracy from attempting to assess such skills as a snapshot during face to face meetings or presentations. It has however been noted that some students are more comfortable in either the online or the face to face meeting situation and that this virtual environment is not seen as replacing the formal design review meeting. Indeed it is desirable to include both as this provides additional opportunities for students to express themselves in a medium which is preferable to them. At the end of the project the supervisor provides a grade and a short report on each student based on a combination of their online and face to face interactions. It is noted that different skill sets are required in the virtual and real worlds and that quite often students need guidance in the appropriate use of both media. Again the interim interview provides an opportunity to discuss with each student their relative competence in these different skill sets.

2.4 Leadership

Not all students volunteer to take a leadership role in these projects. To provide each student with an experience of what it is like to lead the group they are forced to rotate the role at regular periods during the first 12 weeks. The leader acts as chair of the review meetings and is responsible for the agenda and minutes as well as assigning tasks and deadlines. The supervisor attends the meetings, playing the role of the group's senior manager, and afterwards rates all students on their professional conduct. In the second half of the project the groups elect their leader every 4 weeks by secret ballot in which they rank all members. This again uses the students' direct experience to provide additional input into the supervisor's assessment of the leadership qualities of those who have been in charge. The mandatory requirement to act as leader for at least part of the project, while contrived, has received favourable comment in the module review, particularly from those students who would otherwise be reluctant to volunteer as leaders.

2.5 Reflective Critique

In order to assess if students have developed the required skills and not just become aware of what is required in theory they are asked to write an individual reflective critique at the end of the project. This includes a section asking them to reflect on any skills and attributes they have developed during the course of the project which relate directly to the process of team working; specifically the 5 categories in the collaboration section of the peer assessment spreadsheet.

3. EFFICIENCY, ACCURACY & RELIABILITY

3.1 Efficiency

Assessing personal and professional skills requires observation and interaction with students over a period of time. While the cohort size described is relatively small (average of 30) it does still require a considerable amount of time to operate the regime described above. The interim feedback interviews, of around 20 minutes, are seen as particularly important and have been run with 2 supervisors present at each interview to date. This has been done to develop a consistency of delivery but the intention is that these can be done on a one to one basis in future. If however the staff involved in supervision changes the future recommendation would be that any "new" staff member partner with an experienced supervisor for at least one year before operating alone.
The amount of information and discussion threads generated on Google Groups can be overwhelming, particularly at the start of the project when the groups are searching to find a customer need on which to theme their project. While this has proved a very valuable resource for all supervisors it is sensible that only 1 faculty member grade the posts, which requires more time and rigour. To facilitate this a precise marking rubric is essential to ensure consistency across groups.

3.2 Accuracy

In order to encourage the students to provide accurate information to guide the supervisor's assessments it is important to be seen to be fair and accurate in your marking. At the interim interviews students are given an indication of what grade they are heading for in the project and the reasons for their grade. At this point 30% of the marks will have been assigned so there is still much to be gained by the student responding to the feedback and guidance provided. To date this has had a very positive effect on a number of students who have managed to improve their overall grade significantly following this intervention. It is therefore suggested that the grades obtained are more accurate than a model which has only summative assessment and no interim feedback.

3.3 Reliability

In stage 4 of the PDD programme there exists an optional 12 week work placement project (30 ECTS points) which requires a major project to be undertaken. This provides an opportunity for employers to provide feedback on the level of personal and professional skills displayed by the placement students. To date only 4 students have completed such placements (with a further 7 due to complete in June 2010) and so statistics gathered are as yet insignificant. The intention is to continue a longitudinal study which asks the placement employers to grade and comment on the relevant skills. To date the responses have been very favourable but it is anticipated that there will be scope for further refinement and improvement. This real life measurement is seen as having an important input into what is within the university environment only a simulation.

4. CONCLUSIONS AND RECOMMENDATIONS

The development of personal and professional skills can be facilitated by providing numerous group DBT project experiences throughout all years of an undergraduate engineering programme, with staged progression defined by appropriate learning outcomes.

Online tools such as Google Groups can be used to gather relevant input and data regarding the quality and quantity of contributions made by individuals when not in direct contact with project supervisors.

Students can provide valuable information which can be used as supporting evidence in the assessment of personal and professional skills through appropriate use of peer assessment and peer ranking. These inputs may have unreliable accuracy and should not however be used to generate grades, rather be used as additional information to inform supervisor assessments.

The accuracy of peer and self assessment data merits further detailed investigation. The literature suggests that these may be inaccurate but show consistent traits that are related to a student's ability. A study of peer assessment data gathered over the last 5 years is proposed to establish if any characteristics can be observed which it is hoped will inform how the gathering of such data might be improved and utilised more effectively.

The assessment methods attempted to date have proved time consuming, relatively inefficient and potentially of uncertain accuracy due to the subjective nature of the process. In order to guard against this double or triple marking has been carried out while confidence is developed among the assessors that they are at least being consistent in their assessments. Further development of marking rubrics for "softer skills" is required before single marking can be considered robust.

The opportunity to discuss the development of these softer skills, which employers consider important, at interim feedback interviews is seen as worthwhile and is something that had been missing from previous summative assessment regimes for similar group projects.

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THE USE OF CDIO METHODOLOGY IN CREATING AN INTEGRATED CURRICULUM FOR A NEW DEGREE PROGRAMME

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Abstract: The School of Mechanical and Aerospace Engineering at Queen's University Belfast introduced a new degree programme in Product Design and Development (PDD) in 2004. As well as setting out to meet all UK-SPEC requirements, the entirely new curriculum was developed in line with the syllabus and standards defined by the CDIO Initiative, an international collaboration of universities aiming to improve the education of engineering students. The CDIO ethos is that students are taught in the context of conceiving, designing, implementing and operating a product or system. Fundamental to this is an integrated curriculum with multiple Design-Build-Test (DBT) experiences at the core.
Unlike most traditional engineering courses the PDD degree features group DBT projects in all years of the programme. The projects increase in complexity and challenge in a staged manner, with learning outcomes guided by Bloom's taxonomy of learning domains. The integrated course structure enables the immediate application of disciplinary knowledge, gained from other modules, as well as development of professional skills and attributes in the context of the DBT activity. This has a positive impact on student engagement and the embedding of these relevant skills, identified from a stakeholder survey, has also been shown to better prepare students for professional practice.
This paper will detail the methodology used in the development of the curriculum, refinements that have been made during the first five years of operation and discuss the resource and staffing issues raised in facilitating such a learning environment.

Keywords; integrated curriculum, CDIO, design-build-test DBT, product design.

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1. INTRODUCTION

The CDIO Initiative, aimed at reforming engineering education, was established in 2000 by the Massachusetts Institute of Technology and three Swedish universities; KTH - Royal Institute of Technology, Linköping University and Chalmers University of Technology. Queen's University Belfast (QUB) was the first UK University to join the initiative which now has more than 50 collaborating institutions from 25 countries worldwide. Working together and drawing on extensive stakeholder and alumni surveys, the group has produced a syllabus and a set of 12 standards which provide a comprehensive description of the level of knowledge, skills and attributes that graduates of engineering programmes should be expected to acquire. The requirements extend beyond the traditional discipline specific technical knowledge to include product and system building knowledge and skills, personal and professional skills and interpersonal skills. The CDIO approach does not imply that the technical content of a programme should be reduced, but rather that by teaching the discipline in the context of conceiving, designing, implementing and operating a product or system, opportunities to develop these additional skills and attributes are provided at the same time, thus increasing the scope of what can be learned. Further, the CDIO approach demands that programmes are consciously designed to produce the desired learning outcomes derived from the characteristics and abilities identified as requirements by the stakeholders. The Product Design and Development (PDD) degree programme at Queen's University Belfast was the first entirely new degree programme to adopt the CDIO methodology as the basis for its curriculum, accepting its first students in 2004. To formally define the methodology and to serve as a guide to how CDIO might be applied to enhance existing programmes or develop new courses a textbook has been published by the CDIO collaborators. (Crawley et al, 2007)

1.1 Background to the PDD Degrees

One of the first activities carried out by the School of Mechanical and Aerospace Engineering (SMAE) at QUB on joining the CDIO initiative in 2003 was to undertake a stakeholder survey of employers, alumni, staff and students. Primarily this set out to identify the level of proficiency required to be professionally competent engineers in the disciplines already being taught by the School, namely Mechanical, Manufacturing and Aerospace Engineering. 800 hardcopy questionnaires were distributed of which just over 200 were returned. Respondents were asked to rate the level of proficiency required and the importance of items on the CDIO syllabus on a scale of 1 to 5, with 5 being the highest level of importance. The same exercise was also carried out by other CDIO collaborators which additionally allowed for comparison between countries and disciplines to be made. A sample of the survey results covering sections 2 to 4 of the CDIO syllabus is shown in Figure 1.

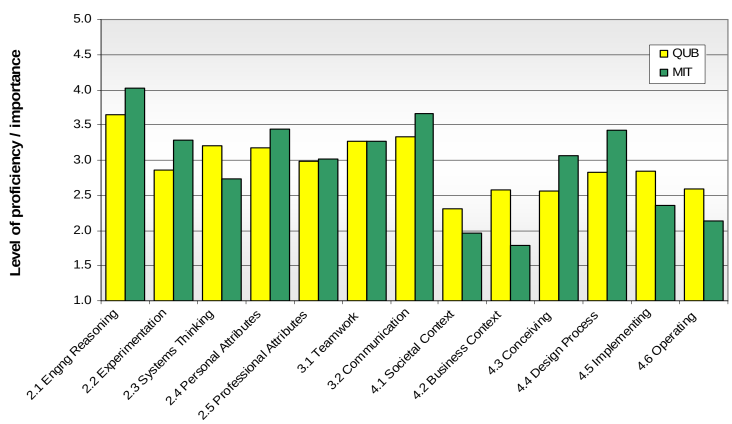

Figure 1: Sample of Stakeholder Survey Results (QUB & MIT)

The QUB questionnaire also asked questions regarding the balance between different areas of the curriculum. Alumni suggested that less time should be devoted to engineering science, mathematics and traditional laboratory experiments and considerably more time to design-build projects and the development of professional skills. This view was not shared among the staff who generally considered that an increased percentage of non engineering science content would effectively "dumb down" the programmes and diminish their quality and value. The challenge presented by the survey was to plan and deliver an integrated curriculum that could meet the expectations of industry in terms of professional skills and attributes without sacrificing the scientific and mathematical rigor of the traditional engineering degree; in essence exactly what a CDIO structured degree aims to achieve.

While a decision was made to improve the existing programmes using the CDIO methodology by means of a rolling programme of managed change, it was also decided that there existed an opportunity to take a more radical approach with the new PDD degree. Starting with a blank sheet of paper the curriculum was designed to fully address all the CDIO standards.

2. CURRICULUM DESIGN

The first 3 CDIO standards are particularly relevant to programme development.

CDIO Standard 1 - CDIO as Context

Adoption of the principle that product and system lifecycle development and deployment - Conceiving, Designing, Implementing, and Operating - are the context for engineering education.

CDIO Standard 2 - CDIO Syllabus Outcomes

Specific, detailed learning outcomes for personal, interpersonal, and product and system building skills, consistent with program goals and validated by programme stakeholders

CDIO Standard 3 - Integrated Curriculum

This standard demands that the curriculum is designed with mutually supporting disciplinary subjects and with an explicit plan to integrate personal, interpersonal, and product and system building skills.

The design brief for the PDD degree was that it would produce graduates who were professionally competent in the process of new product development. This requirement had been identified by a number of strategy documents produced by Government agencies such as InvestNI and was also cited by companies who responded to the QUB stakeholder survey. In addition, subsequent reports such as the “Cox Review of Creativity in Business” commissioned by the UK Chancellor of the Exchequer (Cox, 2005) suggested that there was an untapped pool of creative talent that could reinvigorate the UK technology sector.

As with the development of any product, having identified an unfulfilled customer need, the next phase is to scope the project to establish viability. It was by no means certain that the School had within its resources the ability to deliver a programme that could meet all of the CDIO standards. It was necessary therefore to first establish a logical sequence of progression through the different years of the degree. As a starting point the premise was that subsequent years would cover more of the 4 CDIO phases (Conceive-Design-Implement-Operate) of new product development. Year 1 would focus on the identification of customer needs and the conversion of these into design concepts (C and some D). Year 2 would add more detailed design and manufacturing considerations (C, D and some I) and year 3 would then also include business planning and production management (C,D,I and some O). In this way students would build on previous knowledge in manageable steps until by the end of year 3 they were experienced in all phases of product development as illustrated in Table 1. Bachelor of Engineering (BEng) students study a 3 year programme while Master of Engineering (MEng) students study for 4 years.

Table 1: QUB PDD degree overview

	Focus of content	CDIO phases
Year 1	Creative skills and the discipline of design. Introductory course.	C and some D
Year 2	Focus on design and manufacturing linked to prototyping projects.	C, D and some I
Year 3	Focus on business and management. Major group project.	C,D, I and some O
Year 4	Engineering design and analysis. Work placement / study abroad.	C, D, I, O

The design brief was then expanded from this into a programme specification which includes a comprehensive list of learning outcomes covering knowledge and understanding, subject specific skills, cognitive and transferable skills.

The PDD degree differs from the structure of a traditional engineering degree which can be characterised as having 4 phases. In phase 1 mathematics and science is taught, in phase 2 engineering fundamentals, phase 3 has specialised and elective courses and phase 4 has summative experiences. Fundamentally this type of course is structured around the content and not the context with the curriculum designed to teach disciplinary knowledge in a sequential manner where topics build upon each other. The development of student skills and attributes may not have been planned at all, and any skills acquired happen more by accident than by planning. This may be due to the necessity to operate a modularised and semester based system. Often modules have no relationship to or interaction with one another. In the case of professional skills these are often "bolted on" and delivered by staff from outside the School without context and by non engineers. Students may find themselves in large classes along with others from very different disciplines and the content is often generalised and non specific with no relevant examples which the students can easily relate to. The authors recognise these characteristics well from their own undergraduate experiences in the 1980s and 90s.

CDIO standard 5 requires an introductory course that incorporates design-build experiences followed by at least one further design-build exercise of a more advanced and demanding nature. The development of a new degree offered an opportunity for a radical approach and subsequently a decision was made to develop a curriculum that went beyond this minimum requirement to include a project based course in every year (stage) of the programme that would act as the core of an integrated curriculum.

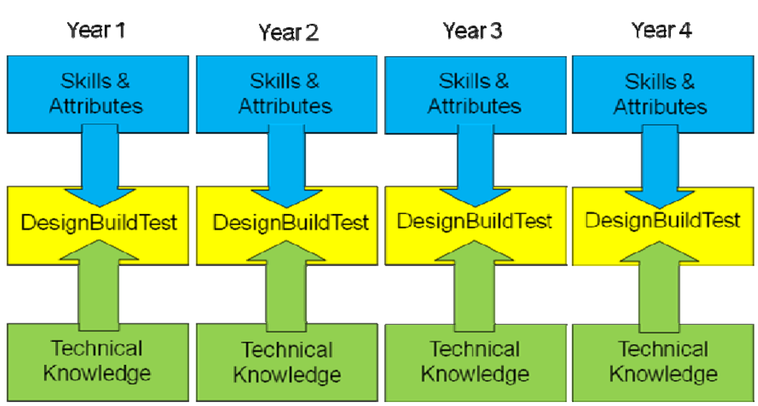

Figure 4: Fundamental structure of PDD degree

Around this core are modules which primarily develop either technical knowledge or professional skills and attributes as illustrated in Figure 4. The opportunity for immediate

application of the skills and knowledge comes through appropriate selection of the themes for the design – build experiences in the core modules. As a generic model the principle is easily understood. What was required however was to develop a detailed curriculum with the appropriate balance of core modules, engineering science and courses focused on skills development. It is also important to select themes for projects in each year which enable the application of the technical knowledge being acquired during the same time period.
Figure 5 shows the authors' assessment of the target level of skills and attributes that can be developed by students successfully completing the DBT projects in the first 3 years of the PDD program. It is important to recognise that while these are objectives they do not necessarily relate to the levels attained by all students on the program. The vertical axis indicates the level of learning in relation to Bloom's taxonomy.

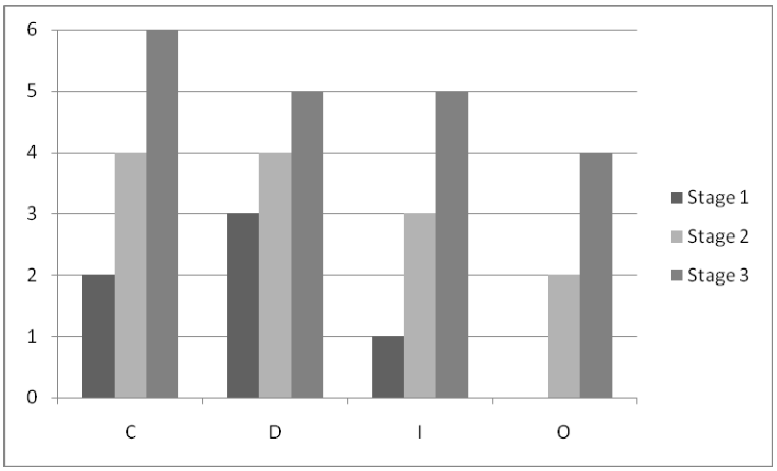

Figure 5: Stepped Development Objectives of CDIO Skills and Attributes in PDD DBT Projects at QUB in Levels Defined by Bloom's Taxonomy of Learning Domains

Conception is lower in stage 1, for example, since the theme of the project is provided and the students only seek to develop incremental improvements to something which already exists (level 3 – application) while a much higher level of conception (level 6 – evaluation) is targeted in stage 3 where original and unique solutions to problems are sought. In all phases (C, D, I & O) a stepped development is mapped out from which learning outcomes are defined and from which tasks and assessment regimes are subsequently devised to deliver these outcomes. This approach is consistent with the constructive alignment model defined by Biggs (1999) and provides clarity to the student between the tasks set and the assessment requirements.

Figure 6 shows the structure of year 1 of the PDD degree with 1.5 core DBT modules "Introduction to Product Design 1" and "Design Project 1" running up the centre of the schematic. Above this are 2.5 modules worth of mostly skills development and below are 2.0 modules of predominantly technical knowledge. It should be noted however that modules are not all one type of learning and indeed through the application of active and interactive learning techniques to all modules, as a result of the work of a Centre of Excellence in Teaching and Learning (CETL) within the School, an increasing amount of skills such as oral presentation are now developed in what had previously been traditional "chalk and talk" engineering science subjects.

The arrows in Figure 6 indicate where there is an opportunity to apply the skills and knowledge to the DBT projects at the core. The detail of how this is done needs to be negotiated between the module co-ordinators under the guidance of the Programme Director who has an overall view of the programme. Additionally the level of all learning outcomes expected in each year need to be considered to ensure that a developmental path is achieved throughout the entire programme of study. To assist in this, Bloom's taxonomy of learning domains is used (Bloom, 1956). The taxonomy categorises learning behaviour into 6 levels (1. Knowledge, 2.Comprehension, 3. Application, 4. Analysis, 5. Synthesis, 6.Evaluation) and provides descriptors and key words to assist in the design and assessment of the learning process. The different levels can be used to indicate the expected performance level of the student by carefully choosing words from the taxonomy when writing the learning outcomes for each module. A more detailed description of how Bloom's taxonomy has been applied to the core DBT modules can be found in the authors' paper presented at the 5th International CDIO conference (Hermon et al, 2009).

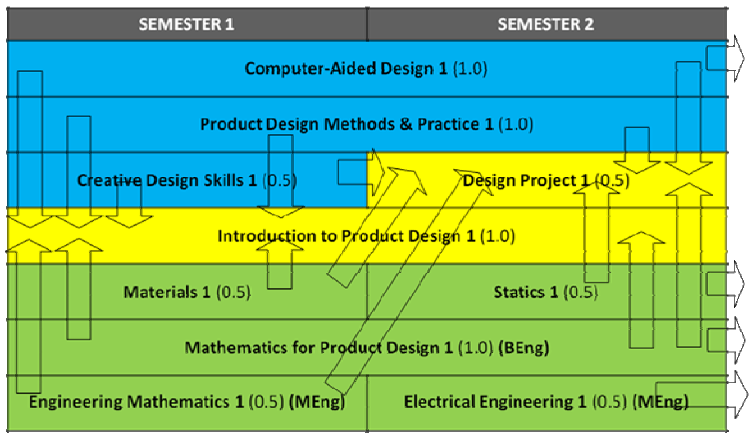

Figure 6: Integrated curriculum – Year 1 PDD

A set of specific learning outcomes for undergraduate programmes is defined in the UK-SPEC published by the Engineering Council UK. The Institution of Mechanical Engineers (IMechE) also uses the same set of outcomes when examining a course for accreditation. There are currently 27 learning outcomes specified across 5 categories which cover both disciplinary knowledge and professional skills and attributes. Part of the IMechE accreditation process focuses on identifying where these learning outcomes are delivered in the modules of a degree program. A matrix is produced for all modules over all years of the degree to help identify any gaps or imbalances that occur. Since a similar approach had been used in designing the new PDD degree to ensure that the relevant learning outcomes of both the CDIO syllabus and UK-SPEC were met, these were transposed with relative ease to the IMechE matrix. The BEng and MEng PDD degrees were submitted for the first time and subsequently accredited by the IMechE in 2009.

3. REFINEMENTS

During the first year of the PDD degree the slot in the timetable now filled by the "Introduction to Product Design" module was taken by a course which concentrated on dissection and analysis of products. A parallel exercise to develop introductory courses for the Mechanical and

Aerospace Engineering degrees (McCartan et al, 2008) to meet the requirement of CDIO standard 4 highlighted that, while using a commendable amount of active and interactive learning, the dissection class was missing opportunities to act as more of a core element in an integrated curriculum. The assessment regime was seen as too narrow and the lack of redesign of analysed products meant there was little chance to apply technical knowledge. By reusing some of the dissection artefacts as a starting point for more design focussed projects, opportunities to apply presentation skills, to produce concept sketches and prototype models have now been created. Group meetings to discuss and evaluate concepts introduce more interpersonal and team working skills and the breadth of deliverables required necessitates time management and efficient use of the team's resources.

In order to mimic professional practice, DBT projects are carried out in teams in all years of the degree. The rationale here is that by changing the members of the groups between projects the students need to adapt to different team dynamics and hence develop better interpersonal and team working skills through this repeated application. The increased number of projects also facilitates deeper learning and gives more opportunities for feedback. It was noted however that by year 4, when a 1.0 module major individual design project is part of the programme, that several students had evidently taken a strategic approach in the preceding years choosing to concentrate on what they were best at so that the team optimised the use of its existing skills. While this may well be accepted as best practice in industry, where the objective is to get the best from the finite resources available, it can serve to reinforce an avoidance tendency in an educational context rather than encourage broader personal development. This characteristic was particularly evident in the area of CAD skills where a "CAD jockey" would often volunteer for this part of the project to the detriment of their personal development in other areas. Consequently other members of the group can also easily become excluded from the CAD activities and subsequently miss the opportunity to develop what is a weaker area of their own skill set. This has been tackled in 2 ways. An additional half module of individually assessed CAD has been introduced at the start of year 2 with tasks which develop skills that can be directly applied to the year 2 group projects in another module. Further, the assessment of the group projects and associated learning outcomes have been modified to include reward for peer mentoring, management and leadership skills. This is assessed by increased supervisor observation including the use of an online project blog and by having sections of the peer assessment spreadsheet refer explicitly to these management and leadership skills. In general the learning outcomes for these projects include an increased percentage of the marks for process rather than product. How the students operate as a project team is assessed as much as the final report and prototype. To be effective this has been backed up by increased interim feedback and monitoring. This, however, has proven to be time consuming and resource intensive. The current focus of development in this area is on achieving the same educational environment more efficiently.

Workspace resources are also an issue which has arisen from the transition of the degree programmes in the School to a CDIO model. Traditional lecture theatres with fixed rows of seating are not suitable for many active and interactive learning activities. The Ashby tower block, which is home to SMAE, is currently undergoing a major refurbishment, due to be completed in September 2010. The requirement for teaching spaces compatible with this new method of teaching has been the key driver in developing the specification of this facility. More small rooms to hold project meetings are required. Additional facilities and material resources for prototyping are also included in the refurbishment plans. Larger team working rooms with freestanding furniture will facilitate a variety of uses. Studio spaces and teaching areas with moving walls will also provide further flexibility.

4. EVALUATION

Built into year 4 of the MEng PDD programme is a 12 week work placement which has enabled an evaluation of the preparedness for professional practice. Employers who act as hosts for these placements are asked to comment on the suitability of the students to the role carried out. The students are required to produce a reflective report of this experience as part of their assessment. This includes a discussion of knowledge and skills from their degree course which have been applied during the placement. In this way a mechanism for continual feedback with employer input has been established as part of the annual programme review (Quality Assurance) process.

During 2009 the School underwent two separate audits of teaching quality. IMechE reassess their accreditation of degree programmes every 5 years, including a thorough examination of the learning outcomes against UK-SPEC. In 2004 the School had just begun to implement CDIO principles to its courses. By 2009 these principles formed the basis of the submission regarding the PDD degree which was being assessed for the first time. In their report (section 3.0 Philosophy, Aims and Objectives) the IMechE visiting team commented that:

> "*The CDIO process is a commendable benefit which has 36 other Institutions worldwide joined up, all operating with real world products, processes and systems. The CDIO is quite a shift in teaching style and the School are fully engaged with staff able to attend the CDIO yearly conferences to give them ownership and full understanding of the best practices in the UK. The documentation showed some previous poor attendance and the CDIO does reflect enthusiasm and an increase in attendance with positive feedback as it encourages team working and a competitive edge.*"
>
> *"The School uses 'Bloom's taxonomy' to determine the level of learning in each year; i.e. remember, understand, apply, analyse, evaluate and create. Mapping these against the different stages of the programme to test the appropriate learning outcomes, this is in conjunction with the mapping against UK-SPEC.*"

Queen's University Belfast also introduced a new internal audit system in 2008, the Educational Enhancement Process (EEP), which focuses on how each School is enhancing its educational provision and the student experience. The EEP panel includes members of academic staff from other Schools in the university, 2 external academics of the same discipline from different UK universities and students from within the School. SMAE was examined under this process in 2009. Section 2 of the panel's report deals specifically with enhancing the quality of education provision and reported that:

> "*Curriculum development is guided by the School's involvement in CDIO and conducted in a top-down manner. Starting from a generalised engineering syllabus, developed by the CDIO consortium, a programme specific syllabus is developed. This syllabus is then evaluated by the stakeholders – students, staff, alumni and industry – to assess its relevance and also to define the required proficiency levels for each of the syllabus items. The results of this exercise, along with subject accreditation criteria enable the development of programme learning outcomes, and then modules and module learning outcomes.*
>
> *A key driver for curriculum development is the desire to better prepare students for professional practice. The Panel were impressed at through the School's general*

involvement in CDIO and at the way in which this approach compliments the University's published policy on employability skills."
"*The Panel also gave its full support to recent developments which were considered to have enhanced the curriculum, in particular the development of the Product Design and Development programmes based on the CDIO methodologies*"

5. CONCLUSIONS

- The CDIO syllabus can be used as an effective basis for curriculum development that is compatible with the requirements of UK-SPEC.
- The PPD curriculum developed at QUB has been endorsed by two independent audits of teaching quality carried out in 2009.
- Ongoing evaluation of student attainment in relation to the stated learning outcomes of the programme has resulted in modifications to the original course structure.
- A change to a CDIO based teaching methodology requires capital investment to develop appropriate teaching workspaces.

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A COMPARISON OF INTERACTIVE TEACHING METHODS USED IN BIOENGINEERING/BIOMATERIALS MODULES AT TWO RUSSELL GROUP UNIVERSITIES

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Abstract: Internationally, biomedical engineering is a rapidly growing field and this is mirrored by an increasing number of dedicated degree courses being developed. The teaching of such multi-disciplinary material to engineering students brings challenges and opportunities. A comparison of interactive teaching methods on bioengineering and biomaterials modules at two Russell group universities was undertaken. Each module was taken by fourth year MEng students as well as taught MSc students therefore cohorts were similar in this respect, as were student numbers. Another similarity is that these modules are not part of bioengineering or biomaterials degrees, but options of mechanical engineering and materials degree programs. At each university, techniques included invited industrial lectures, small group assignments and presentations, alongside traditional lecturing practice. Student feedback showed that the range of teaching approaches were positively received and appreciated.

Keywords; interactive learning, bioengineering, biomaterials.

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1. INTRODUCTION

Internationally, biomedical engineering is a rapidly growing field and this is mirrored by an increasing number of dedicated degree courses being developed. In the United States, bioengineering is the most rapidly growing field of engineering when compared with all other disciplines including mechanical, electrical, civil, and chemical engineering (American_Society_for_Engineering_Education, 2008). In the UK, many bioengineering and biomaterial courses have appeared at both undergraduate (Joyce, 2009a) and postgraduate (Joyce, 2009b) levels. The teaching of such multi-disciplinary material to engineering students brings challenges and opportunities. For example, challenges include introducing students to a new language associated with medicine and anatomy alongside a need to understand some biological processes. Conversely opportunities include the applications of multi-disciplinary engineering in areas which have a direct and positive impact on people's lives. Both authors of this paper were keen to apply interactive learning methods in their respective bioengineering and biomaterials modules. They believe that such interactivity leads to deeper learning among their students. Moreover, following a constructivist approach the lead author saw his role as acting as a facilitator and, wherever possible, allowing his students to experience the benefits of peer-to-peer learning within an encouraging and non-hierarchical setting (Kahn and Walsh, 2006). The aim of this paper was to compare teaching and learning approaches at two universities and disseminate these approaches.

2. METHODOLOGY

A comparison of interactive teaching methods on bioengineering and biomaterials modules at two Russell group universities, Newcastle University and Queen's University Belfast (QUB) respectively, was undertaken. Each module was taken by fourth year MEng students as well as taught MSc students therefore cohorts were similar in this respect, as were student numbers (typically 20-30 students per module). Another similarity is that these modules are not part of bioengineering or biomaterials degrees, but options of mechanical engineering and materials degree programs. In the School of Mechanical and Systems Engineering at Newcastle University, the Bioengineering module is a 15-credit module. Prior to the 2008-09 academic year the Bioengineering module was 'traditional' in the sense that it consisted of lectures, tutorials based on question sheets and a written exam which gave 100% of the module assessment. In the 2008-09 academic year, the lead author became module leader and for his third of the module introduced changes based on his pedagogical beliefs and experience. A focus was made on interactive learning rather than data transference. In addition, assessment for his third changed to project-based rather than exam-based. The project concerned a critique of a currently available total joint replacement. Project based learning encourages deep rather than superficial learning (De Graaff and Kolmos, 2007) while studying an artificial joint which is currently implanted into patients conveys relevance to students.

In the School of Mechanical and Aerospace Engineering at QUB, two modules relating to Biomaterials and Biomedical Engineering are offered as optional modules to the final year students on the MEng in Mechanical Engineering and compulsory modules to the postgraduate students enrolled on the taught MSc program in Polymer Engineering. The modules are entitled: (1) Biomaterials and Tissue Engineering; (2) Design and Performance of Medical Devices, and represent 15 ECTS credits. The second author is responsible for 50% of the teaching and assessment of these modules. The aforementioned modules at QUB have been offered from 2008; prior to their introduction (from 2003-2007) a module relating to Medical Materials was offered to the MEng and MSc cohorts. In both cases, these modules were assessed by continuous assessment (20%) and a final written examination (80%). The continuous assessment is a group-based project (n=2-3 students) conducted over 5 weeks, whereby each group selects a research paper from a predefined list. Subsequently, each group has to conduct an extensive literature review and source two additional research papers relating to the initial paper selected, thereafter all three papers are critiqued by the group and the salient points from each paper delivered as an oral presentation. This format of continuous assessment encourages a deeper understanding, greater level of engagement and interaction in the subject. Moreover, this research-led approach also transfers very important skills to the student such as conducting literature review, critically appraisal of research papers, development of presentation skills and encouraging group dynamics.

Within each module, teaching techniques included invited industrial/clinical lectures, small group assignments and presentations, alongside traditional lecturing practice. For example, interactive teaching methods included:

- A small-group exercise to aid anatomical understanding through the use of models of human joints
- A 2-hour visit to the University's Dissection lab to examine cadaveric hip and knee joints under the supervision of the Director of Anatomy
- A small-group assignment based on the analysis of physical examples of total joint replacements
- A small-group assignment based on analysing the engineering drawings related to a two-piece finger prosthesis
- A small-group assignment assessing current literature in terms of contrasting and comparing clinical issues between metal-on-polymer, metal-on-metal, ceramic-on-ceramic and metal-on-metal hip resurfacing prostheses.
- Small group based workshops using relevant 3D models to assist in understanding the anatomical features and characteristics of bone, organs and articulating joints.
- Discussion forums were utilised to encourage debate and rationale thinking relating to the important issues that need to be considered when designing and manufacturing prosthetic implants or medical devices.
- Small group based assignments focusing on pertinent research issues relating to Biomaterials, Tissue Engineering and Medical Devices.
- Preparation and oral delivery of short presentation (10 minutes) based on the research findings of the aforementioned small group based assignment. There was a questions and answers element following the delivery of the presentation and students were actively encouraged to ask questions to the peers.
- Demonstrations of surgical procedures through the application of videos with commentary from surgeons (e.g. orthopaedics and cardiovascular surgery).
- Invited lectures given by practitioners in the fields of orthopaedics, restorative dentistry, cell biology, anatomy and pharmacy.
- Invited lectures given by professionals working with major medical device and biomaterials companies (e.g. biomaterial scientists, bioengineers, intellectual property protection, clinical and regulatory affairs).

As can be seen both authors employed small-group working as frequently as possible as they believed this was a proven method of achieving deep learning within students, as well as it providing a more enjoyable and interactive experience for students and staff alike (Kahn and Walsh, 2006). Moreover they wanted their students to have a significant (rather than a boring or trite) learning experience (Dee Fink, 2003). Such a methodology allowed case-based, problem-based, research-led and project-based learning, where students' learning was organised around attempts to solve original problems that occur within the areas of biomaterials and bioengineering. These methods can help students develop the conditionalised knowledge and understanding that lets them think productively about problems in the discipline (Harris et al., 2002). Equally, both authors regularly employed the skills of practitioners and professionals working in the areas of Biomaterials and Biomedical Engineering. The rationale for adopting this was three-fold: (1) to ensure that students fully appreciated the truly interdisciplinary nature of this subject area, (2) the role that an engineer or scientist has within the field and (3) the exciting employment opportunities that are available for students who have successfully completed these modules.

For the bioengineering module at Newcastle University the lead author evaluated his third of the module through an open-ended, anonymised questionnaire which was offered at the end of his third of the module. The first part of the questionnaire consisted of ten questions which were to be answered on a five-point scale. These questions to students included: ‘the proportion of classes you attended’; ‘the difficulty of the module relative to others’; ‘the lecturer’s interest and enthusiasm for their subject’; and ‘your overall rating of teaching on the module’. There was then a section which asked students to give two positive aspects and two suggestions for improvement of the third of the module taught by the lead author. Additional sections then asked students to comment on specific aspects of the module. These included the use of Primal Pictures anatomical software which was used to quickly make students familiar with anatomical and medical terms related to the human body in general and orthopaedics in particular (Joyce, 2009c). Another section requested similar information regarding the use of human joint models. A third section asked for feedback on the interactive, small-group working while a final section requested comment regarding the visit to the dissection lab. Data was obtained for both the 2008/09 and 2009/10 academic years, though the visit to the dissection lab was first introduced in the 2009/10 academic year.

For the Biomaterials and Biomedical Engineering modules offered at QUB the second author evaluated his half of the modules using student questionnaires that were completed anonymously at the end of the 12 week program of study. The first element of the questionnaire consisted of 15 assertions that were to be responded to on a five-point scale. These assertions included: ‘module's relevance to my degree programme was explained clearly’, ‘teaching was effective and relevant to the module aims and objectives’, ‘good interaction and feedback between students and lecturer’, ‘workload was appropriate to the module size’ and ‘rating for teaching of module’. The final element of the questionnaire asked students to comment on the ‘most satisfactory aspects of this module’, the ‘least satisfactory elements’ and ‘how the lecturer could assist your learning on this module’. Data was obtained for both the MEng undergraduate students and MSc taught postgraduate students during the 2008/09 and 2009/10 academic years.

3. RESULTS

For the bioengineering module at Newcastle University, student feedback from the 2009/10 academic year to two of the specific questions relating to interactive small group working is shown in figures 1 and 2.

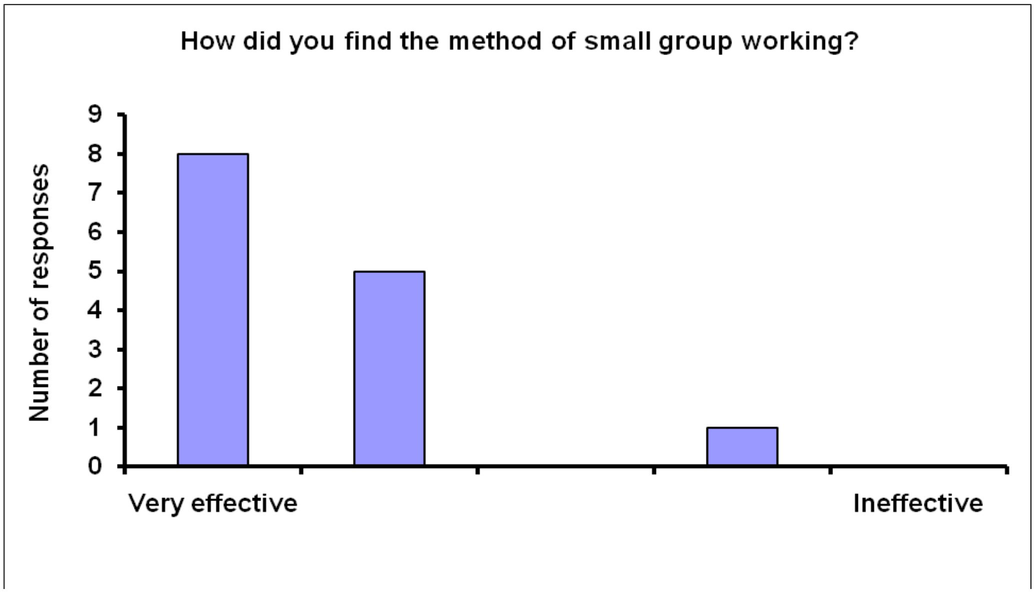

Figure 1 – Student responses to first question on small group interactive learning.

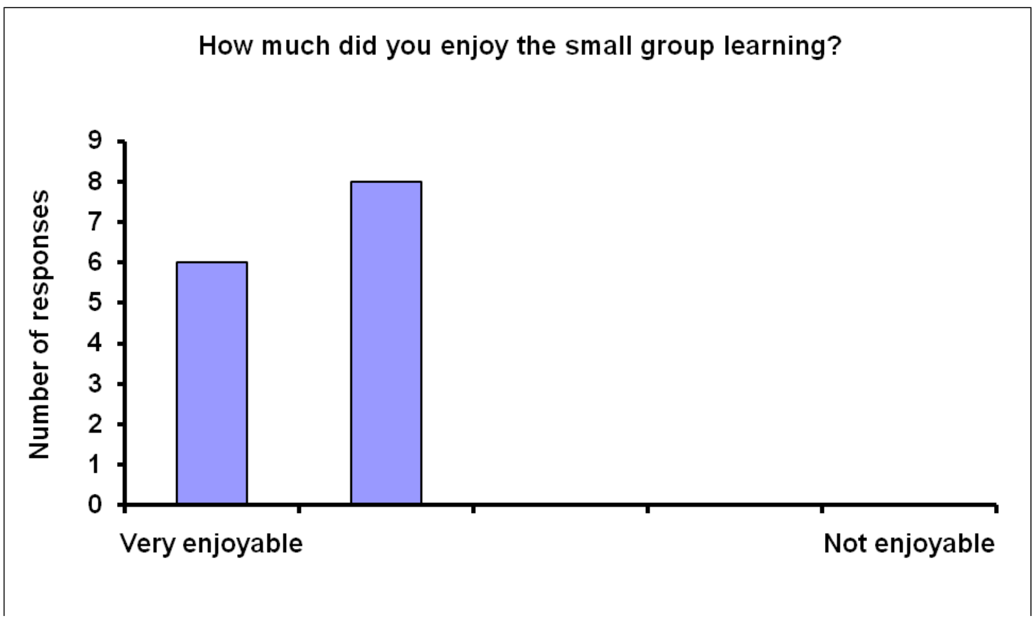

Figure 2 – Student responses to second question on small group interactive working.

Student comments on other aspects of the module included the following. For the interactive Primal Pictures software statements included: 'a really useful tool and very easy to use'; 'excellent and useful software'; and 'good to have access outside of lecture times, gives you chance to play about with it when you're in the right mood to work'. However, students would have preferred some additional developments as indicated by the comments: 'could be improved to include the ability to drag joints to make them move'; and 'would be good if you could zoom out onto a hand/foot/knee from the whole skeleton rather than having to hunt through tabs'. Regarding interaction using the models of human joints, student comments included the following: 'the clearest way to see and understand joint anatomy and movement'; 'good to get hands on, helped to gain an understanding about the scale of the joint'; and 'very interesting to

see models you can touch, the dynamic models were a great addition'. For the visit to the dissection lab and interaction with human joints the greatest praise was received: 'awesome experience'; 'fantastic class, helped to reinforce what we had learnt in classes, good to see firsthand how the materials differ and are similar to those of the prostheses'; 'extremely useful in understanding the joints and creating interest in the module'; 'greater appreciation for the complexity of the human body'; 'great chance to see real examples of joints and their relative movements'; and 'if time permits we should have more of these in future'. Where examples of 'two good features' of the module had been requested, student comments included: 'completely new and different from other modules in conventional (Mechanical) modules'; 'hands on use of models/making class think'; 'varied teaching methods helped to spark interest (talk and medical school visit)'; 'interactive learning, medical school, models, primal pictures software, etc'; 'interesting project'; 'lecturer's interest'; 'the structure of lectures'; 'the models shown for explanation'; 'very interactive'; and 'lecturer very enthusiastic about his subject'.
For the Biomaterials and Biomedical Engineering modules at QUB, student feedback from the 2009/10 academic year to two of the specific questions relating to interactive small group working is shown in figures 3 and 4.

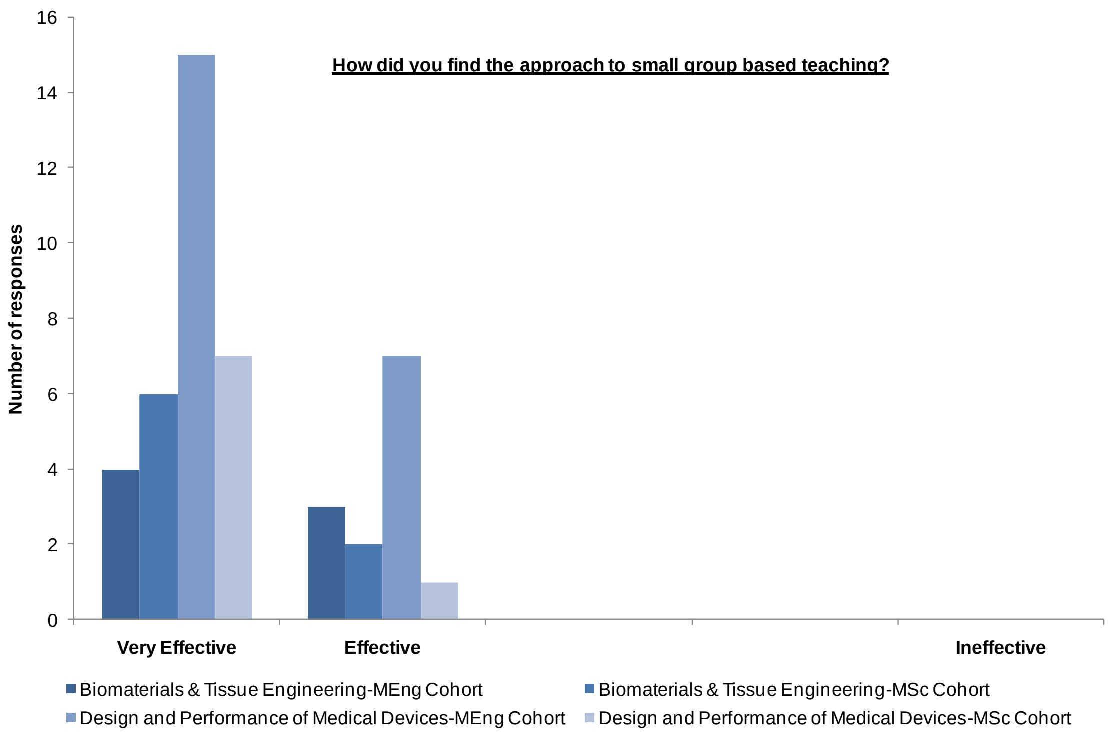

Figure 3 – Student responses to question on small group based teaching.

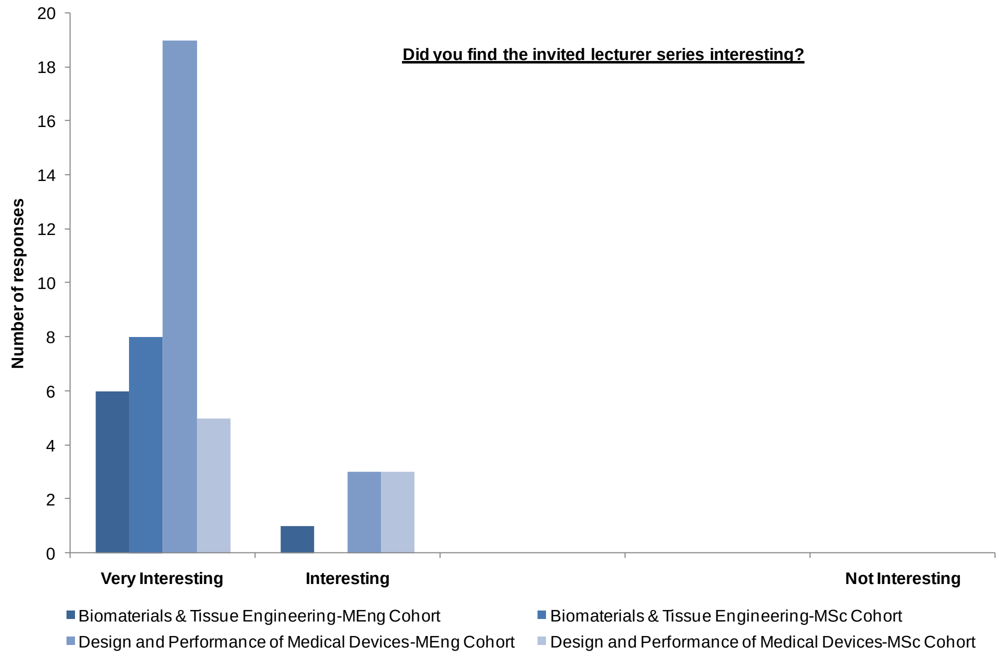

Figure 4 – Student responses to question on invited lecturer series.

Student comments relating to other positive aspects of the Biomaterials and Tissue Engineering module included the following. 'Good insight into biomaterials and applications', 'excellent teaching approach to use of materials in medicine', 'loved learning a complex new area', 'enthusiasm of lecturer and his experience made the module very interesting', 'really enjoyed the research based assignment...might even do a PhD now', 'found the discussion on what makes bone very interesting', 'engaging subject matter with many real world examples', 'enjoyed the research based coursework that allowed for development of new skills', 'program of guest lecturers very interesting', and 'all topics were extremely interesting and completely different to the rest of the Degree programme ... loved it'. With respect to the Design and Performance of Medical Devices module, student comments on the positive aspect of the module included: 'stimulating learning experience for the student', 'loved the real world applications to engineering', 'module provided greater understanding of how complex joints are', 'greater understanding of how medical implants are designed to work in the body', 'enjoyed the videos showing the role of an orthopaedic surgeon', 'a lot of useful and relevant examples shown during the module, enjoyable and very interesting learning experience', 'enjoyed the pace of the module and the found the lecturer very interesting, wholly different to other modules', and 'good student-lecturer feedback'. Comparing the comments and feedback from the undergraduate MEng and postgraduate MSc students taking the modules, it was observed that both sets of students had similar positive views. However, the postgraduate MSc students did make reference to the fact that they needed to spend additional time on the computational elements of the modules, particularly with respect to the Design and Performance of Medical Devices module. Specific comments included: 'some of the formulae relating to measurement of wear was challenging', and 'numerical questions in tutorials took longer to understand, but got there in the end'. These comments are not surprising as the students enrolled on MSc degree program in Polymer Engineering are materials scientists, chemists, biologists and chemical engineers and therefore would not be as proficient at engineering calculations when compared to their MEng undergraduate peers. The least satisfactory aspect regarding both modules delivered at QUB can actually be seen as a positive, that is a number of students (n = 6) would have liked to have experienced these modules earlier in their Degree programme. Student comments relating to this point included: ‘would have liked to have had this module earlier in my degree’, ‘stimulating subject, why did we not have this module in second year’, and ‘would have been good to experience topics like this earlier in course’.

4. DISCUSSION

The authors of this paper are bioengineers and this specialisation facilitates some of the teaching approaches undertaken. For example, the setting of student assignments based on the very latest research papers chosen by staff. Also, the two authors have a wide network of industrial and clinical collaborators whom they can invite to participate in modules. Despite these caveats staff and students both report positive learning experiences from the various bioengineering and biomaterials courses. One issue the lead author recognises is that of cultural differences between students. While UK and European students may be familiar with showing initiative and being relaxed with small group working, for some students from different educational backgrounds, where perhaps knowledge is expected to be received from the knowledgeable Professor, such interactive learning methods can be disconcerting. This may be why a small number, one per year to date, comment negatively on the five-point scales regarding small group working. However, as the questionnaires are deliberately anonymised, it is difficult to validate this assertion. Overall though, as can be seen from student comments, the majority of students have enjoyed and benefited from small group and interactive learning.

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AN ENGINEERING DESIGN COURSE: DEVELOPMENTS OVER FIVE YEARS EMPHASISING TOPICS OF SUSTAINABILITY

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Abstract: Engineering design is a core subject in many Engineering departments and is greatly valued by future employers. Over five years a second-year engineering design course has been nurtured to focus on developmental projects associated with sustainability which emphasise hands-on learning. Students work in groups, with recent projects focusing on the design of domestic scale wind turbines. The design is taken from concept through manufacture to final testing using a wind tunnel. The commercial and societal relevance of the project is emphasised, as is the need for team working. Each team is given a budget of £100 (€110). The majority of the timetable is devoted to laboratory sessions where hand and power tools are available. Assessment methods include presentations, formal reports, 'weekly updates' and individual logbooks. Learning outcomes are based on UK-SPEC. Creativity and innovation are encouraged during the design process. Regular assessment occurs throughout with an emphasis on rapid, formal feedback. Student feedback improves year on year with typical student attendance above 90%. The number of students taking the Design degree stream doubled last year. The key features which have led to success are allowing students to take a paper design through to manufacture (encompassing the hands-on and 'realistic' aspects of engineering) and trusting in students' creativity. Both areas led to students having a sense of ownership of their learning and developing into professional engineers. Assessment workload for staff is high but is seen by students as evidence of staff commitment to their learning.

Keywords; sustainability, project-based learning, hands-on learning, problem-based learning, andragogy.

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1. INTRODUCTION

The School of Mechanical and Systems Engineering School at Newcastle University in the UK currently offers a three-year BEng degree in Mechanical Engineering together with a suite of four-year MEng degrees in Mechanical Engineering based disciplines. All degrees are accredited by the Institution of Mechanical Engineers or the Institution of Engineering and Technology. As with many such degrees in the UK, engineering design is seen as a core subject. At the School of Mechanical and Systems Engineering, engineering design is taught at first and second year. First year Design is a 20 credit module which includes: the study of structures; an introduction to AutoDesk® Inventor® solid modelling software, the production of engineering drawings; an introduction to BS8888 (the British Standard on Technical Product Documentation, specifically the Specification for defining, specifying and graphically representing products); a bridge design, build and test exercise; and an introduction to machine shop equipment and processes.

In the School of Mechanical and Systems Engineering, a second year cohort typically consists of 70 students, though this number increased markedly to 94 in the 2009-10 academic year. The second year Design module was worth 15 credits (out of a total of 120 credits for the year) and teaching took place over two terms. Four hours per week of contact time were allocated, broken down into a one-hour lecture and a three-hour slot where the students worked in their groups. Beginning in the 2005/06 academic year, students worked in pre-assigned groups of 5. Through an ongoing Knowledge Transfer Partnership (KTP) [a UK government sponsored scheme to encourage interaction between universities and industry] that one of the authors had established, a design project was set up with a local company which manufactured Caravans (Explorer Group, Consett, UK). Projects in academic years 2005-06 and 2006-07 concerned the design of folding bed mechanisms. Each were 'paper' exercises in that the final output included a full set of engineering drawings and a written group report, although one student won a summer placement with the company and his design went into production the following year.

Assessment was by a group presentation and a group report at the end of each term. Groups were told to decide on the allocation of marks for group members. In addition, in part as a method of assessing and rewarding individual contributions, each student had to keep a 'logbook' which served as a contemporaneous record of their contribution to the design project. Logbooks were assessed at three points: early in term 1 to check that fundamentals were being adhered to; at the end of term 1 alongside the group 'interim' reports; and at the end of term 2 again alongside the group 'final' reports. In summary, assessment was completely through course work and consisted of the following components: logbook; interim group report; final group report; interim presentation and final presentation.

1.1 Module developments since 2007

In 2007, following the departure of the previous module leader, the lead author of this paper was appointed module leader. This also meant that the second year Design module was reduced to three members of teaching staff (the authors of this paper). Based on previous experience of teaching the module, discussions with colleagues, feedback from students and various pedagogical ideas, specific changes were made to the module which were intended to improve the student learning experience. Some aspects of the Design course were maintained. Group projects based on open-ended learning were continued to ensure that creativity was prioritised and that students had a sense of ownership of their project and thus of their learning. In addition, those aspects of the marking methodology based on peer-informed assessment were maintained. Assessment continued to include individual logbooks, and interim and final group reports. However it was felt that improvements could be made. Firstly, student feedback supported comments by staff that a caravan based project was somewhat lacking in inspiration. In addition the authors felt that a more socially relevant and topical engineering project would enthuse the students more. The academic year 2007-08 project was entitled 'greening our homes'. The design project initially required students to come up with three conceptual designs of domestic scale energy saving devices or energy generation devices. These three concepts were described in a 3,000 word interim report after which one concept was taken forward and designed in full during the second term. This description formed the basis of the 3,000 word final report.

One key aim was to introduce concepts related to sustainability. As will be appreciated these concepts can apply to many areas of engineering. In the earlier projects they could have been applied to caravans. However concepts of sustainability were explicitly stressed when the new module leader took over. Therefore issues such as choice of materials, considerations related to recycling etc were emphasized to students and sustainability was made one of the marking criteria which were shared with the students. In addition, issues related to global warming and fossil fuel usage were covered in an early lecture so that the context of the need for sustainable power generation was set at the beginning of the module.

In the academic year 2008-09 access to student workshop space was obtained as well as a wind tunnel. The 2008-09 design topic had a title of ‘from kilobytes to kilowatts’. Here, ten groups of students, of no less than seven per group, were initially given a redundant computer and printer. From these they had to design and manufacture a wind turbine, which was tested in a wind tunnel at the end of the first term. No additional material or components were permitted. In the second term, having learnt from this experience, each group was given a budget of £100 and allowed to take their original design of wind turbine forward, or re-design, as they saw fit. In both terms, laboratory space was set aside for manufacture and assembly of the wind turbines using basic hand tools.

There were concerns over the assessment methodology and burden from previous years, especially when staff numbers had been reduced from four to three in 2007. Having two ‘peaks’ of assessment at the end of each term was felt to reduce student effort at the early and mid-term points. Therefore the final presentation was removed, while the interim presentation was reduced in duration, as these were felt to take up a significant amount of student and staff time when the bulk of the assessment marks was obtained from the project reports. Marks which had been allocated to the presentations were passed to a new form of assessment, named the ‘Weekly Update’.

Over the course of the two terms each group had to submit seven Weekly Updates. Each Weekly Update consisted of two sides of A4. The first side aimed to summarise the previous week’s project work by asking open-ended questions such as: what information sources had been investigated and what data had been gained from them; how had the design progressed that week; what challenges had been overcome; and what were the aims for next week. The intention of these questions was to allow students to see the progress they had made and appreciate their successes in the design process. It also mimics the sort of progress report required in industrial design and production projects.

The second side of the Weekly Update listed the parts of UK-SPEC which it was felt the Design module covered. UK-SPEC are the components by which degree courses offered by UK higher education institutions are assessed for accreditation by the engineering institutions. It is also the standard by which Chartered status (similar to PE in the USA) is obtained in UK and many international Institutions. Components of UK-SPEC are grouped into areas including: E - Engineering Analysis; D - Design; S - Economic, Social & Environmental Context; and P - Engineering Practice. As just a few examples of the 18 that were felt to be covered by the Design module, these included: D4 – use creativity to establish innovative solutions; P8 – ability to work with technical uncertainty; and S3 – understanding of the requirement for engineering activities to promote sustainable development. These UK-SPEC components were shared with the students so that they became aware of the criteria against which the School is assessed. Thus the students had an opportunity to see if the claims of the course, in terms of meeting many UK-SPEC, could be met. In addition the criteria by which the School and its degree programmes were judged, were shared with students. For each Weekly Update students were asked to give examples of which UK-SPEC had been met.

The mark allocation of these Weekly Updates was intended to encourage both individual and group effort. As there were seven Weekly Updates, so each member of a group was made responsible for one Weekly Update. This individual was allocated a mark out of 5% of the total Design course assessment. Another 3% was assigned to the group. Weekly Updates were marked and returned together with feedback to students the week after they had been handed in. Feedback was given to each group in turn, so that each group had dedicated feedback with all the potential benefits of this. The Weekly Update was limited to two sides of A4 so that marking time was minimised and the document facilitated regular and rapid feedback.

Full attendance at all Design classes was strongly encouraged through the taking of registers and it was felt that peer-group pressure also supported high attendance rates. In the first week of the module a group essay related to sustainable development was set. This exercise gave students an introduction to the forthcoming design project. A straightforward change introduced in 2007-08 was to use Blackboard™. This served as a depository for all course documentation, background reading and allowed quick communication with the student cohort. Group size was increased slightly, from six in 2006-07 to seven in 2007-08 and 2008-09. In summary, the assessment (and % marks) for academic year 2007-08 onwards consisted of a group essay related to sustainable development (5%), an Interim Report (33%), seven 'weekly' updates (21% + 5%), and a Final Report and Logbook assessment (36%).

The School of Mechanical and Systems Engineering gathers feedback from students on all of its modules. This allows a comparison of student opinion on all modules. From 2007-08 the current Design module leader introduced an additional and more comprehensive feedback form for the module. The anonymised form consisted of ten questions which were answered on a 5-point scale. In addition there were four open-ended questions where more qualitative data could be obtained. Informal feedback was gathered during the course and the ongoing interaction with the different groups provided copious opportunities for feedback.

2. STUDENT FEEDBACK, AUTHORS COMMENTS AND OTHER RESULTS

In the years in which the Design course has run in the form of group projects there have been very few students who have failed the module. Those who have failed have not engaged and contributed to the group and have been penalised by the group. Such students have consistently failed many other modules within the second year and have left the School or, on just one occasion, re-sat the entire year. For the academic years 2005-06 and 2006-07 informal student feedback showed that students enjoyed and felt they benefitted from many of the aspects of the group work. However, there was less enthusiasm about the caravan related projects, despite its linkage to local engineering industry and the ‘prize’ of a summer work placement with Explorer Group where the ‘winning’ design could be taken forward to be manufactured and included in a caravan. For these reasons the 2007-08 Design module was changed as outlined above.

In all academic years formal feedback was gathered from students. For 2007-08 formal student feedback showed high satisfaction with the course. From the closed questions the lecturers’ interest and enthusiasm in the subject was particularly highly rated by the students. From the open ended questions students positively acknowledged the creativity allowed them in the projects as well as the topic of ‘green’ engineering. Interestingly the value of the Weekly Updates was also appreciated by the students who noted how this document helped them in the design process by highlighting their project’s progress and encouraging them to examine their ability to meet UK-SPEC requirements that related to their project.

For 2008-09 student feedback has been even more positive. Fifty seven of these anonymised questionnaires were returned in 2008-09, and these results will be focussed on in the following sections. Students commented very positively on the module and their learning experiences. For example, that students felt that they learnt a great deal and applied engineering knowledge was shown by the following comments: ‘I feel as though I have learnt more in this module than the entire 1st year’; ‘improved a whole range of skills rather than just dry theory’; ‘a lot was learned from the achievements and failures’; ‘it was good to apply what we have learned’; while another student felt a positive aspect was the ‘application of knowledge gained from past years’.

Confirmation that students felt that they enjoyed the learning experience, and recognised that it was different to ‘traditional’ lectures was shown by the following remarks: ‘very enjoyable, made learning not a chore’; ‘enjoyable to put knowledge into practice’; ‘good fun therefore a better atmosphere for learning’; refreshing to not always have lectures, but to learn ourselves’; ‘enjoyable learning process’; and one longer statement included ‘taking the project into our own hands allowed the team to explore the project in many ways and determine our objectives and achievements. Again this allowed a more advance learning into the project, whereas if it was taught, then the opportunity to ‘explore’ would not be permitted’. Students also acknowledged that ‘research played a huge role into finding solutions, and with all this research provided self learning which probably could not have been absorbed if it was taught in lectures etc’.

Evidence that students felt that they had experienced professional engineering was supported by the following comments: ‘the course gave the feeling that I was working as a real engineer’; learning professional engineering skills’; ‘it was a good way to get introduced to professional engineering’ and one team described themselves as ‘a group of young future professional engineers who now have experience in managing long-term engineering projects as part of a team’. That students enjoyed the hands-on aspects of the module was shown by the following comments: ‘we actually got to do stuff’; ‘a lot has been learnt through the duration of the entire project, knowledge which could not have been conveyed from lecturer to student other than through (this) type of practical learning’.

Evidence that students valued ‘green’ and realistic projects was clear from the following comments: ‘applying engineering for relevant project (environmental issues)’; ‘able to apply this course to real life’ and ‘it was refreshing to actually apply engineering knowledge to a real application’. That the opportunity of creativity was recognised and appreciated was shown by the feedback: ‘encouraged imaginative thinking’ and ‘creativity that you do not get from any other module’. Additional positive comments included: ‘made new friendships within the group’; ‘the course was run in a professional manner and we were treated as such’; ‘money to spend/be trusted with’; ‘whole process from design concept to testing showed continuity’; and ‘budgeting and component sourcing from companies’. One student commented at length in his log book as follows. ‘Design has been a truly challenging project, involving lots of engineering tasks, decisions and justification in order to make the project a huge success. With the involvement of designing, manufacturing, as well as cost management and time keeping, it prepares what might be experienced when in industry. Not only has this project been an eventful learning process, but also invaluable skills and experiences have been obtained, such as working with others in a team, to organising and contributing’. He continued: ‘What has been particularly interesting and enjoyable is the designing of the turbine itself. It allowed myself to express the creative and innovative side of me and really applied the ideas. Nothing is more rewarding than to see what you’ve created in actual use, and to see it working is overwhelming’. Such very positive comments have led the lecturing staff to judge the module a great success.

From the ten questions that were answered on a five points scale, the longitudinal student answers to the question “Your overall rating of teaching on the module” for the academic years 2007/08, 2008/09 and 2009/10 are shown in figure 1. There were 52 responses in 2007/08, 57 in 2008/09 and 82 in 2009/10. The increasing number of responses in 2009/10 was due to the fact that the student cohort increased in size that year and also that attendance at the feedback lecture was more strongly encouraged. As can be seen the overall responses were positive and have improved over time, with the slight ‘tail’ removed in the latest year.

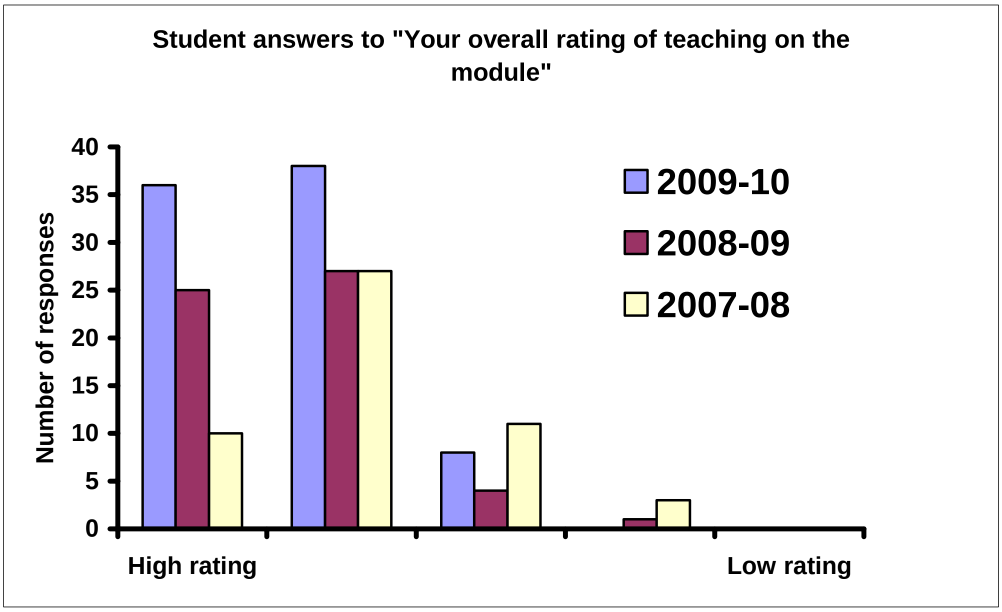

Figure 1 student feedback over three academic years to the same question

Attendance was monitored at all classes and was always above 90%. This success was felt to be due to a combination of factors. Firstly that an attendance register was taken and groups who had individuals missing were asked to explain why this was. Attendance and professional behaviour was linked to success as a future engineer in business rather than just attending another class. Secondly it was felt that students enjoyed the course so much that they wanted to attend, a feeling that was compounded by positive peer-group pressure. In terms of academic quality, it was judged that the students' designs were of a high standard. From the 2007-08 cohort, one student took a year out to take advantage of an industrial placement as he had been so inspired by his group's design. Upon returning he is developing the design, of a thermostatic valve for domestic radiators, for manufacture.

3. DISCUSSION

For the academic years 2005-06 and 2006-07 the students all passed but there was limited enthusiasm for a caravan based design projects. For 2007-08 and 2008-09 this was countered by a 'green' engineering theme which it was anticipated would interest the students, while creativity in the design process was maintained by offering open-ended projects. Formal written feedback from the students showed that both creativity and relevance were achieved. For 2007-08 laboratory space was requested for term 2 to allow models of the students' design to be made. Unfortunately, this did not happen due to space and timetable restrictions. However it did occur in 2008-09, over both terms, and the students responded positively. If a student contributed to the group then it was unlikely they would fail the Design module. The few failures were due to a low allocation of marks from the group, through the peer-moderated marking scheme. All failures that occurred were associated with students who performed very badly across all their second year modules, not just Design. The peer-moderated marking scheme was felt to be just and to work well, supporting literature which suggests that it can give a fair assessment of student input into team projects (Willmot et al., 2008).

There is a great deal of literature which supports the use of project based learning (Abdulwahed et al., 2008). Such project based learning is said to be a constructivist pedagogy practice and to offer a student centred approach (Abdulwahed et al., 2008). Moreover the real or quasi-real aspects of the projects are said to offer relevance to students (Abdulwahed et al., 2008). Similarly there is a wealth of material to support the use of challenge based or enquiry based learning (Bramhall et al., 2008; Powell et al., 2008) in which students are given greater responsibility for their own learning. Feedback from students taking the Design course indicated that they enjoyed this challenge of designing, building and testing their wind turbines, and they felt they learnt more from this process than they would have from 'conventional' lectures. Additionally the benefits of hands-on work to engineering students have been recognised (Lambert et al., 2008) and this opinion was supported by student feedback from the Design module.

One issue, given the high staff workload, is the long-term viability of the course. While the authors recognise the high workload they are enthused by the positive reaction of students to the course and to their input. Such intrinsic rewards justify, in their opinion, the high workload. They also feel that the module has been, and continues to be, developed through a team approach and with input from each member. Therefore, while losing one current member of staff would be challenging, it would be hoped that any new member of staff would quickly appreciate the ethos of the module and bring their own perspective to this positive environment.

In the Design module, lecturers see themselves primarily as facilitators (Lambert et al., 2008) although some lectures are given in which technical information is offered. For engineering students, the value of being an experienced and skilled team player as well as being a good engineer has been recognised (Steiner et al., 2008). It is felt that the experience gained during the Design course will help students in this respect. Moreover the shared learning aspects of group working should be appreciated too (Powell et al., 2008; Johnson, 1999). It is felt that the Design module has been improved year on year, with parallel increases in student satisfaction and student learning. Part of the ethos of the module can be supported by comments taken from the 2005 ‘Educating Engineers in Design’ publication from the Royal Academy of Engineering: *And what do we need to teach? We don’t. We need to give the opportunity to gain experience and awareness in multi-disciplined team environments and let the confidence of youth loose on a prepared world. What can we give students in a university department? Experience of working in multidisciplinary teams working on realistic projects.* (Royal_Academy_of_Engineering, 2005)

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USE OF WEB-BASED SOFTWARE AND JOINT MODELS TO TEACH ANATOMY TO ENGINEERING STUDENTS

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Abstract: Human anatomy is a complex subject but how can engineering students, with little formal background knowledge, be quickly taught this intricate and new topic? Innovative teaching materials in the form of web-based anatomical software and human joint models were introduced into a Masters level bioengineering course two years ago. In the current year a visit to a dissection lab was added and, based on student feedback, dynamic models of human joints were purchased and introduced. For the software and the models bespoke teaching documents, which students worked through in pairs or small groups, were produced by the author. Anatomy and the associated language can be seen as a dry, difficult and peripheral subject by engineering students. Therefore an aim was to use multiple, hands-on and interactive methods to help students to learn anatomy quickly. Student feedback has been collected over two academic years and has been equally positive about learning from the software and the models of human joints. In addition the author noted that students appeared to interact well with the teaching materials and the small group working encouraged discussion and sharing of opinion. At approximately £4,400 (€5,000) for one year's access for ten seats, the software is expensive. Combining the positive learning benefits of non-hierarchal, small group and peer-to-peer learning with innovative and novel teaching aids quickly and effectively enhanced the student learning experience of atypical material by a cohort of engineering students.

Keywords; bioengineering, anatomy.

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1. INTRODUCTION

One of the fascinating yet challenging aspects of modern engineering is its remarkably multidisciplinary nature. Straightforward examples include mechatronics, where a combination of mechanical engineering and electronics are successfully realised in millions of consumer products. Another multidisciplinary example is bioengineering, and data from the United States shows this to be the fastest growing area of undergraduate engineering education in the USA (American Society for Engineering Education, 2008). In such nascent fields there is the need to quickly and effectively introduce engineering students to sciences and subjects they may have not met previously.

Bioengineering improves medical interventions in many ways and one of its most important contributions has been through the design of replacement joints, the most well known of which are probably those for the hip and the knee. How can engineering students quickly and effectively be taught human anatomy and gain a full understanding of the associated medical language such as coronal, metacarpophalangeal and inversion-eversion? One innovative method of learning could be provided through the use of dedicated software related to the anatomy and physiology of the human body, and by employing models of human joints.

In the School of Mechanical and Systems Engineering at Newcastle University, the subject of Bioengineering is taught as a 15 credit module over two semesters to a combined group of fourth year MEng undergraduate students as well as postgraduate taught MSc students. Historically, two members of academic staff taught the module, taking 1/3 and 2/3 shares of the teaching load. On alternate years they swapped the teaching load so that one year one taught 1/3 and the next he taught 2/3 of the module content. Course delivery and assessment previously followed a conventional pattern of lectures and tutorials with assessment based on a written examination at the end of the module. In the 2008-09 academic year the author of this paper became module leader and began to teach on the module. Based on his pedagogical views and experiences a number of changes were introduced to the Bioengineering module. For his ‘third’ of the module, assessment was swapped from final exam to an individual, 3,000 word project based on an engineering critique of a commercially available design of total joint replacement. As such a critique needs to be founded on a full appreciation of the anatomy of the human joint that is being replaced, so the challenge was how to facilitate student learning of the complex subject of anatomy. In addition, for the majority of the bioengineering students, this would be the first time they had been formally introduced to anatomy and the associated medical terminology. In the 2009-10 academic year a third member of staff became involved in teaching the module, so that the share of teaching became 1/3, 1/3, 1/3. In the 2009-10 academic year, the author of this paper delivered similar teaching content to the 2008-09 academic year, focussing on total joint replacement.

Functional anatomy is a strongly three-dimensional subject where spatial visualisation is key (Van Sint Jan et al., 2003). Commentators have noted that medical students frequently encounter problems in understanding certain dynamic aspects of functional anatomy (Van Sint Jan et al., 2003) and this is likely to be the case with engineering students too. It has also been shown that the application of multimedia has helped students to increase their 3D anatomical understanding by giving them spatial direction about the underlying anatomy and its dynamic behaviour (Van Sint Jan et al., 2003). Additionally it has been noted that if students can interact with lecture content, then their assimilation of that material should be increased compared to situations where there is no opportunity to interrelate (Benbunan-Fich, 2002).

By gaining a full understanding of the anatomy of human joints, the author of this paper intended that his Bioengineering students would appreciate the inherent challenges of joint replacement and the problems facing clinicians who have to implant such devices. To aid with this anatomical understanding the author of this paper was able to incorporate dedicated anatomical software as well as models of human joints into his teaching. The anatomical software chosen was Primal Pictures Systemic edition. Details of the software can be found on the company’s website (http://www.primalpictures.com/). To date no formal independent evaluation appears to have been published and this paper may therefore offer the first such pedagogical assessment of the software. The models of human joints were purchased from 3B Scientific (Weston-super-Mare, UK). Models of the shoulder, spine, knee, hand, hip and foot were obtained.

In the academic year which the Primal Pictures software was introduced, 2008-09, the author taught one third of the Bioengineering module, with a focus on total joint replacement. After a series of lectures on total hip replacement and biotribology which introduced background knowledge through a case study of the most common and successful type of joint replacement, students were allocated an individual project. In their projects each student was asked to critique a specific design of replacement joint and describe the anatomy of the relevant natural joint. Deliberately each of these projects was intended for one of the less commonly replaced human joints, specifically the shoulder, elbow, wrist, ankle and the various finger and toe joints.

This methodology allowed case-based, problem-based, and project-based learning, where students' learning was organised around attempts to solve authentic problems that occur in bioengineering. Such methods can help students develop the conditionalised knowledge and understanding that lets them think productively about problems in the discipline (Harris et al., 2002). This strategy was repeated in the 2009-10 academic year, except that projects became paired. There were also two additions to the teaching. The static joint models were augmented with dynamic joint models, those that could be flexed in the same directions as human joints. Secondly, a two-hour visit to the dissecting room of Newcastle University's Medical School was arranged. Here, students were supervised by the Director of Anatomy and given access to human knee and hip joints.

2. METHODS AND MATERIALS

Dedicated teaching materials were provided to the students in the form of bespoke training notes, written by the author, for the Primal Pictures software. Students worked through these notes with the software, in pairs, at their own pace, during dedicated sessions. The author of this paper led these sessions and was available to answer any questions which arose around anatomical principles or medical terminology. Similarly, the author produced bespoke training notes in relation to the human joint models. Here, students worked in self-selected groups to answer pre-set questions based around the models.

It has been noted that valuable features of web-based learning include its potential for empowering the learner, for enabling individualised instruction and collaborative peer-to-peer learning, and for transferring greater control to learners to decide when, how much, and to what extent study and instruction takes place (Curran et al., 2000). By presenting information and instructional materials in various formats, individual learning styles and preferences can be addressed (Curran et al., 2000).

By signifying that a fundamental understanding of anatomy is required to tackle subsequent assessed course material related to artificial joint replacement, and by pointing out how many people have their lives improved through joint replacement, it was considered that the 'need to learn' and the 'want to learn' aspects of Race's model of learning would be facilitated (Race, 1994). Supervision was deliberately small group or one-to-one and non-hierarchical so that students felt they were gaining personal attention in a constructive learning environment, as suggested by Tinto's model of integration (Tinto, 1975). Additionally the value of providing time for student-instructor and student-student interactions in the classroom has been shown (Roselli and Brophy, 2003). Students were paired up to tackle questions related to the software, and formed self-selected groups to answer questions related to the human joint models, thus encouraging immediate learning by doing and augmenting this through peer-to-peer learning. Both of these tactics supported Kolb's ideas of experiential learning, thus facilitating deeper learning (Kolb, 1984). Moreover, it has been recognised that opportunities to work collaboratively can enhance students' abilities to learn and can help students receive feedback about their thinking.

In both the 2008-09 and the 2009-10 academic years, at the end of his third of the module, anonymised questionnaires were passed to the students by the author of this paper. The questionnaires contained a number of sections and were intended to gather feedback on this part of the Bioengineering module. The first section of the questionnaire consisted of ten questions which requested answers on a five-point scale. The second section asked the student to offer two good features of the course and two suggestions for improvement, before offering the opportunity for further comments to be made. The third section focussed on the 'innovative' features of the course, including the Primal Pictures software and the human joint models. Here the dedicated questions were 'to what extent did Primal Pictures software help you to understand human anatomy?'; 'if you accessed Primal Pictures software outside of taught sessions, to what extent was this useful?'; and 'to what extent did human joint models help you to understand human joint anatomy'. For the 2009-10 academic year another question was added requesting feedback on the visit to the dissecting room of the Medical School of Newcastle University.

3. RESULTS

Students interacted well with the software and asked very few questions related to navigating around the software, while the pairing mechanism encouraged pertinent discussion and sharing of opinion. It was also interesting to note the majority of students mimicking the actions of human joints shown on computer screens, for example by lifting their shoulders to imitate elevation or 'wagging' fingers to copy their flexion-extension motion.

Student feedback on use of the Primal Pictures software was overwhelmingly positive. Students said that using the software was 'fun' and 'easy' and one commented specifically about the learning experience, 'the Primal Pictures software made me appreciate what a sophisticated and still not fully understood bearing the natural elbow joint is'. One student described the software as 'an excellent graphical aid and introduction to the anatomical language'. Another said the Primal Pictures software was 'very useful for the project, in naming bones and muscles and all related terms to do with the joint'. A fourth student offered this review of the software. 'It was very good for learning about the muscles, ligaments and bones considering you had to click on each part'. A fifth student wrote 'the Primal Pictures software was a huge help in understanding anatomy of joints'.

Another student offered the following verdict: 'I found the software easy to use with its simple search and contents options'. 'It was easy to navigate through the program'. 'What I found most useful about the software were the interactive 3D models of the area of interest which could be rotated and altered. When looking at a specific joint it allowed me to appreciate the complexity of it in 3D but also made it very accessible to explore as each component within the joint could be highlighted by clicking on it, then the name and a brief description was given at the side of the model. The 3D models could also be built up layer by layer from the bone showing the different tendons, ligaments, muscles etc which allowed you to simplify your view of an otherwise complex "organ" within the body'.

Perhaps the most interesting comment about the Primal Pictures software was the following: 'With the program being so simple to use it urged me to look at other sections of the body out of interest purely as a learning experience. The program overall does not give a great deal of in-depth information about specifics within the body but its greatest ability is to show otherwise complex organs, joints and systems within the body in an interactive 3D way which is very user friendly'. As with any software, suggestions for enhancement were offered. These included: 'could be improved to include the ability to drag joints to make them move'; and 'would be good if you could zoom out onto a hand/foot/knee from the whole skeleton rather than having to hunt through tabs'.

Two formal questions were asked of the students regarding the software, and an answer requested to each on a five-point scale. These questions were: 'to what extent did Primal Pictures software help you to understand human anatomy?'; and 'if you accessed Primal Pictures software outside of taught sessions, was this useful?'. In the 2008-09 academic year, twenty completed questionnaires were received from students, although one student did not respond to the second question. In the 2009-10 academic year there were fourteen questionnaires completed. Results are shown in figures 1 and 2.

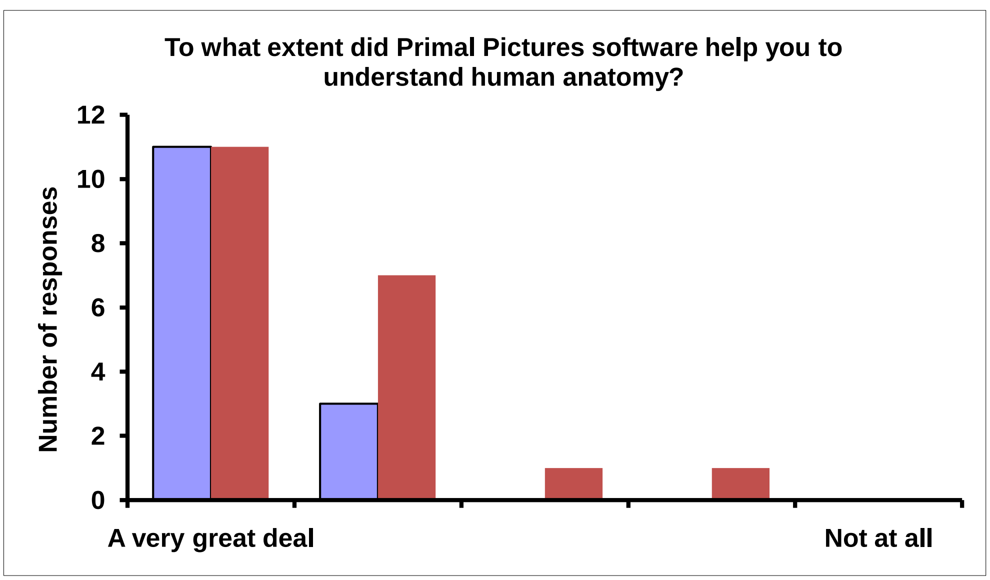

Figure 1 Students' answers to first specific question on use of Primal Pictures software (2009-10 academic year in blue, 2008-09 in red).

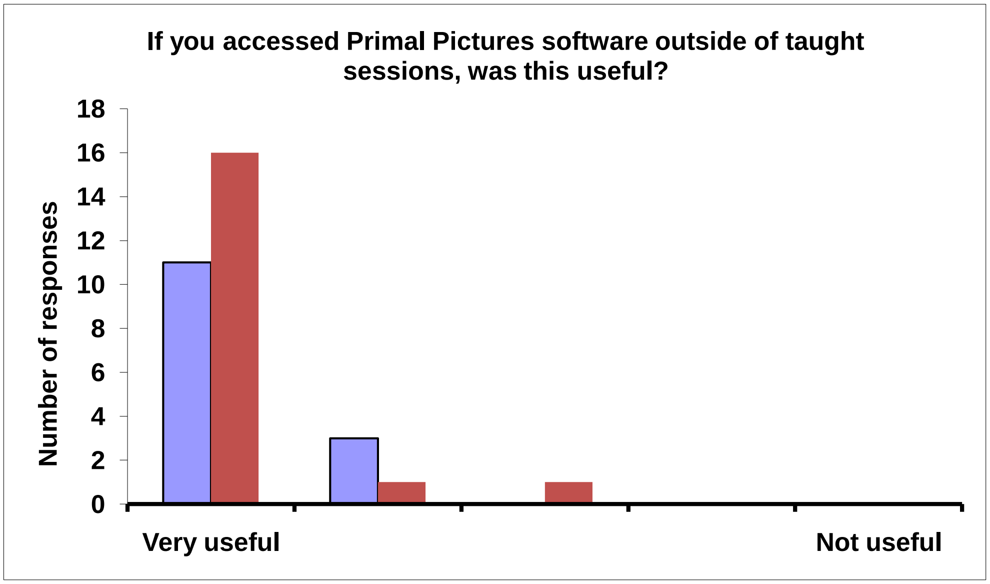

Figure 2 Students' answers to second specific question on use of Primal Pictures software (2009-10 academic year in blue, 2008-09 in red).

As can be seen from figure 1 the majority of students (90% in 2008-09 and 100% in 2009-10) thought that the software helped them to understand human anatomy a 'great deal' or a 'very great deal'. In addition, as indicated in figure 2, the majority of students (94% in 2008-09 and 100% in 2009-10) thought that it was 'very useful' or 'mostly useful' to be able to access the Primal Pictures software outside of the taught sessions. The feedback on the human joint models was equally as positive. Responses to the question 'to what extent did human joint models help you to understand human joint anatomy' are shown in figure 3. As can be seen, the majority (80% or 16/20 in 2008-09, and 86% or 12/14 in 2009-10) answered in the two highest categories available.

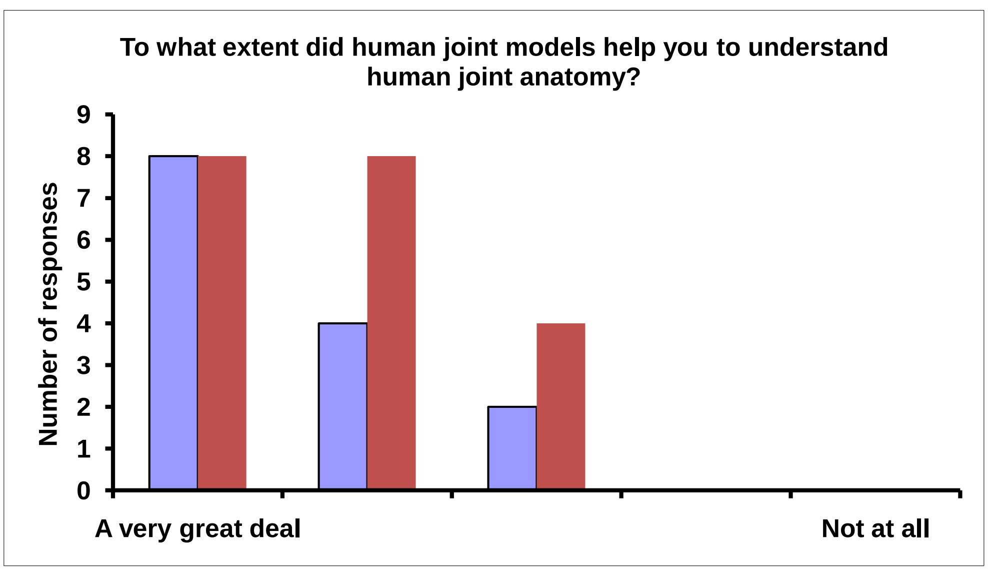

Figure 3 Students' answers to question on use of human joint models (2009-10 academic year in blue, 2008-09 in red).

From feedback at the end of the 2008-09 academic year, one student voiced the opinion that dynamic models, those which could be articulated, would have been preferred. This had been the original intention, but issues of cost (dynamic models are approximately three times the cost of static models) meant that less expensive static versions had to be selected. However, taking a lead from this student feedback, funding was obtained to allow the purchase of a small number of dynamic models (Adam Rouilly, Sittingbourne, Kent, UK). These were employed alongside the static models in the 2009-10 academic year.

As has been stated, in the 2008-09 academic year each student was assigned an individual project which concerned a critique of a currently available artificial joint. As part of this evaluation, students were asked to describe the anatomy of the relevant natural joint, describing the main bones, muscles and ligaments. The average mark awarded on this section of the projects was 62% and almost all the students had used Primal Pictures software to describe the appropriate natural joint thereby indicating the important role that the software had in their understanding of anatomy. This situation was repeated in the 2009-10 academic year, again almost all of the students employing data from the software to describe the joint they were critiquing.

Throughout his third of the module, in both academic years, the author of this paper employed small group and interactive teaching wherever possible. General feedback from students should therefore be seen in this light but students' comments as to positive aspects of the module included the following: 'entirely new and interesting topic, self directed learning (project)'; 'the project is good and I learned a lot'; 'very interactive learning, encouraged thinking/problem solving'; 'the software was useful, the teaching was very clear to us'; and 'course work assessment, no biology knowledge assumed'.

For completeness, it was also interesting to note student comments on their visit to the dissecting room of the Medical School of Newcastle University in the 2009-10 academic year. These remarks included: 'awesome experience'; 'fantastic class. Helped to reinforce what we had learnt in classes. Good to see firsthand how the materials differ and are similar to those of the prostheses'; 'extremely useful in understanding the joints'; 'greater appreciation for the complexity of the human body'; 'great chance to see real examples of joints and their relative movements'; 'anatomy class was superb'; and 'if time permits we should have more of these in future'.

4. DISCUSSION

The software is expensive, at approximately £4,400 (€5,000) for one year's access for ten seats. However, it can be accessed from any computer connected to the World Wide Web, so that students are not restricted to where or when they can learn. Formal feedback showed that students appreciated this flexibility. According to the Primal Pictures website, the software is used in over 450 universities in more than 20 countries and in 2010 over 500,000 students will use it to learn anatomy. While the testimonials on the website are upbeat, no formal independent evaluation of the software appears to have been published; therefore this paper may offer some of the first such observations.

As with the software, there appears to be little in the pedagogical literature assessing the usage of human joint models. These were far less expensive and remain available for future years, and student feedback on them was almost as positive to that for the software. Student comments regarding the human joint models included: ‘the clearest way to see and understand joint anatomy and movement’; ‘good to get hands on, helped to gain an understanding about the scale of the joint’; and ‘very interesting to see models you can touch’. For the 2009-10 academic year, dynamic models were used alongside static models. The difference between the two types was noted by student comments including ‘the dynamic models were a great addition’ and ‘the models that move are much more effective than the static ones’.

In conclusion the anatomical software, augmented by the use of models of human joints, allowed students to rapidly become familiar with a new area of learning from outside engineering. Combining the positive learning benefits of non-hierarchal, small group and peer-to-peer learning with innovative and novel teaching aids quickly and effectively enhanced the student learning experience of atypical material by a cohort of engineering students.

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EMBEDDING 'LEARNING & THINKING STYLES' INTO ENGINEERING MATERIALS COURSES

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Abstract: An area identified as useful for both staff and new students is 'Learning & thinking styles'. The majority of new students join the department being used to teaching styles that might be totally different to those they encounter in their first year at University. In addition if they are not aware of the different styles of teaching & learning they could potentially find themselves overwhelmed by any apparent lack of 'understanding' or failing to make the 'connection' with a subject.

Providing new students with awareness of their particular learning styles we hope to help them overcome any possibilities of 'mismatch' with the way various subjects being taught, as well as support them in improving on the weak sides of their learning capabilities. This is seen as part of the overall process of educating the 'complete' engineer, 'Broad minded, ethically and ecologically responsible agent of social and material change towards a socially just and ecologically sustainable world', not only in demand by industry but an absolute necessity for our societies when facing up to the challenges of the 21st century.

Having done this kind of work as part of research into 'Teaching and Learning' over a period of years with 1st year tutees, discussed by Kapranos (2007 & 2008), the process was until recently not formalised. The paper presents the results from the experience of running this scheme as part of an Introduction Week & Skills Week combination and discusses any possible benefits from embedding 'Teaching and Learning' as seen through personal feedback from students.

Keywords; embedding skills in engineering education, learning and thinking styles.

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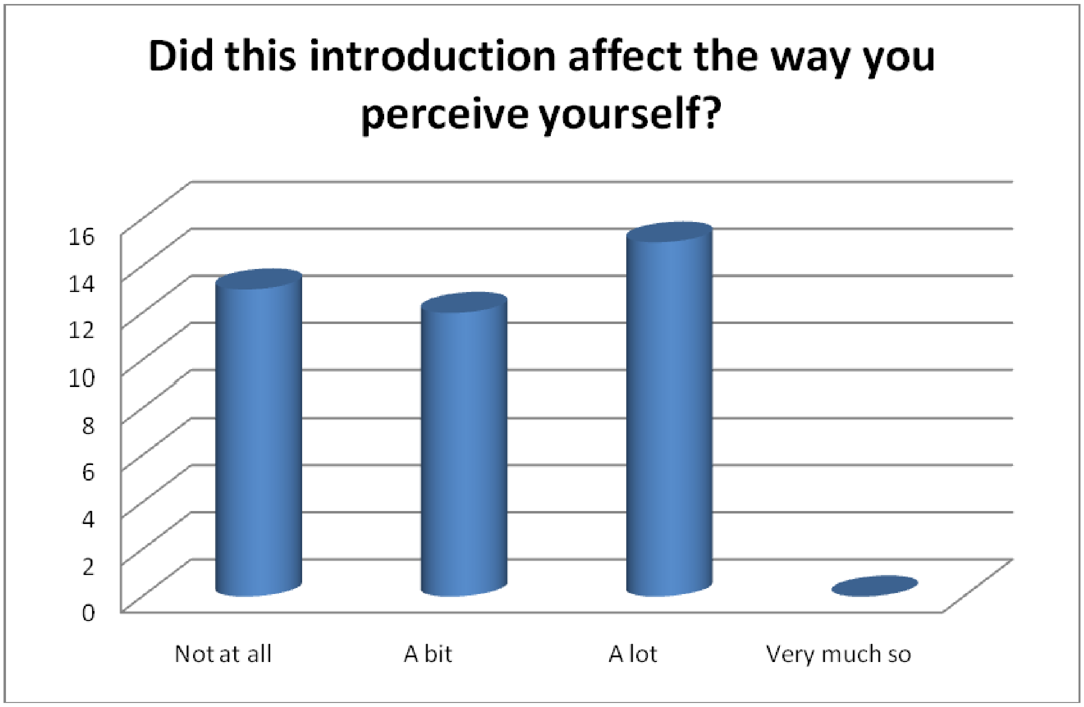
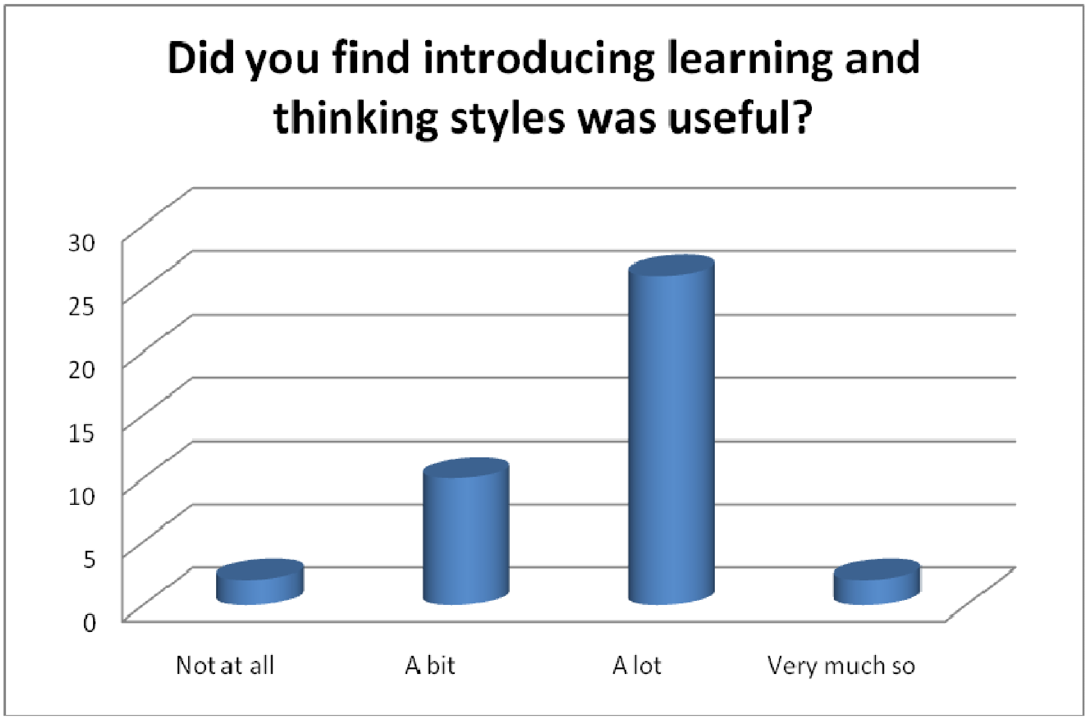
1. INTRODUCTION

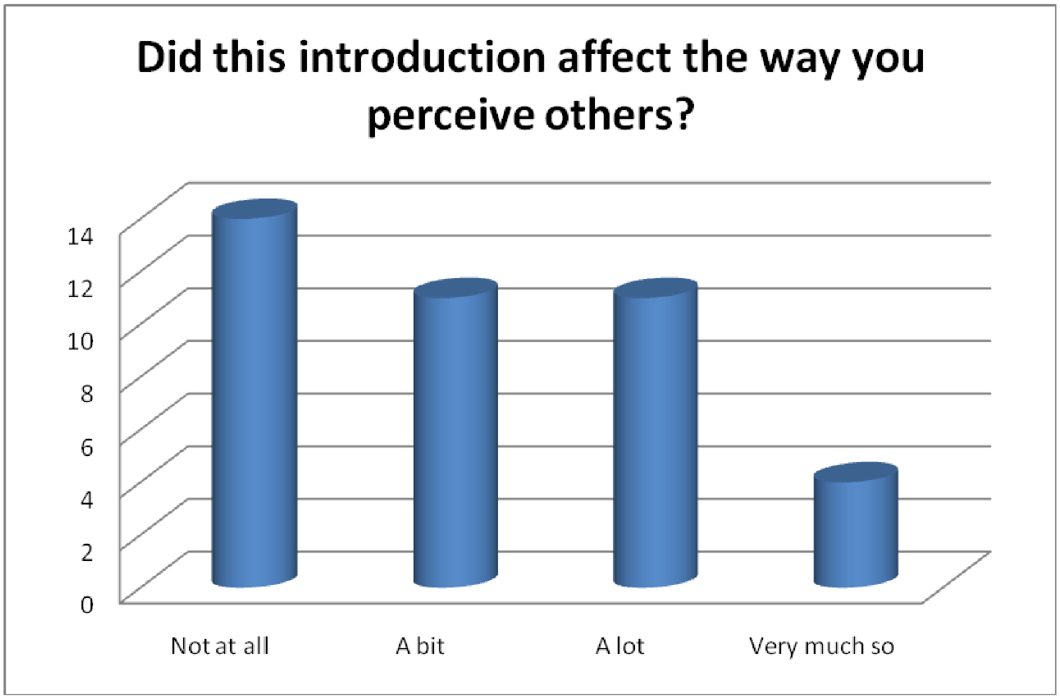
1.1 Intro-Week - What's Your Learning and Thinking Styles?

Learning styles refer to the ways students prefer to approach new information. The questions they preferred offered them insight about how they learn, what their primary and secondary processing styles were. Advice was given to them at the time as to how to take advantage of their learning styles in order to learn more efficiently. For example, if the primary learning style was visual, they could draw pictures in the margins, look at graphics and read text that explains the graphics. Envision a topic or play a movie and think of how they would act out the subject matter. If their primary learning style was auditory, they could listen to the words as they read, try to develop an internal conversation between themselves and the text and don't be embarrassed to read aloud or talk through the information. If

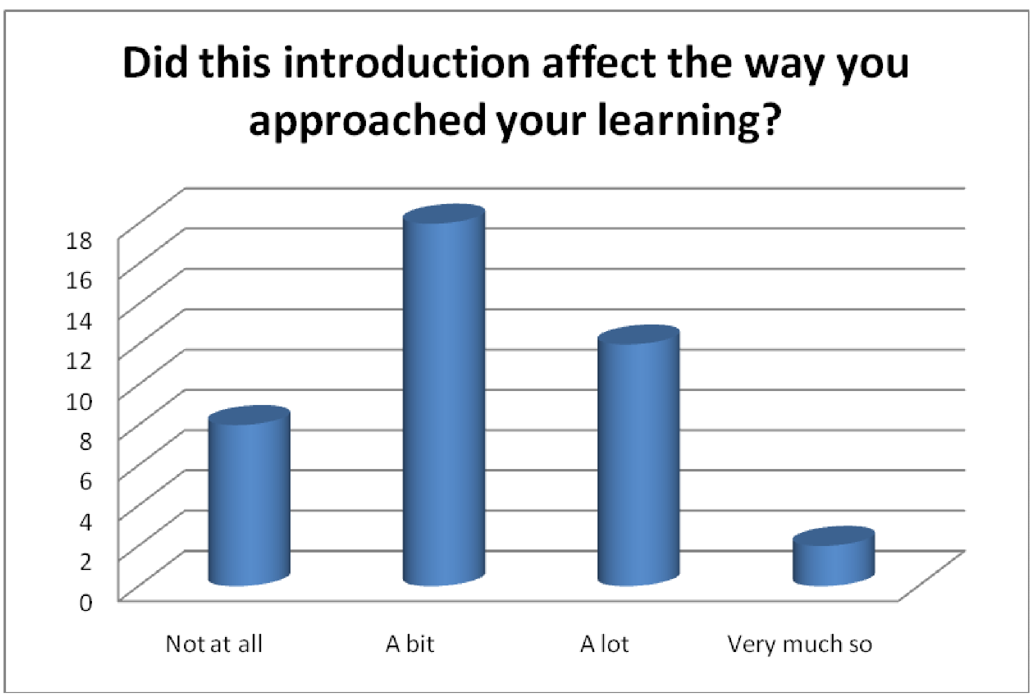




on the other hand their primary learning style was tactile/ kinaesthetic, they were encouraged to use a pencil or highlighter pen to mark passages that are meaningful to them, take notes, transferring the information they learn to the margins of a book, into a journal, or onto a computer. Doodle whatever comes to mind as they read, hold the book in their hands instead of placing it on a table, walk around as they read, feel the words and ideas, in general to get busy—both mentally and physically.



It was discussed that not only do we all have our preferred learning and working styles but we also have our favourite thinking styles. It was shown that Concrete Sequential Thinkers tend to be based in reality. They process information in an ordered, sequential, linear way. Concrete Random Thinkers are experimenters. Abstract Random Thinkers organize information through reflection, and thrive in

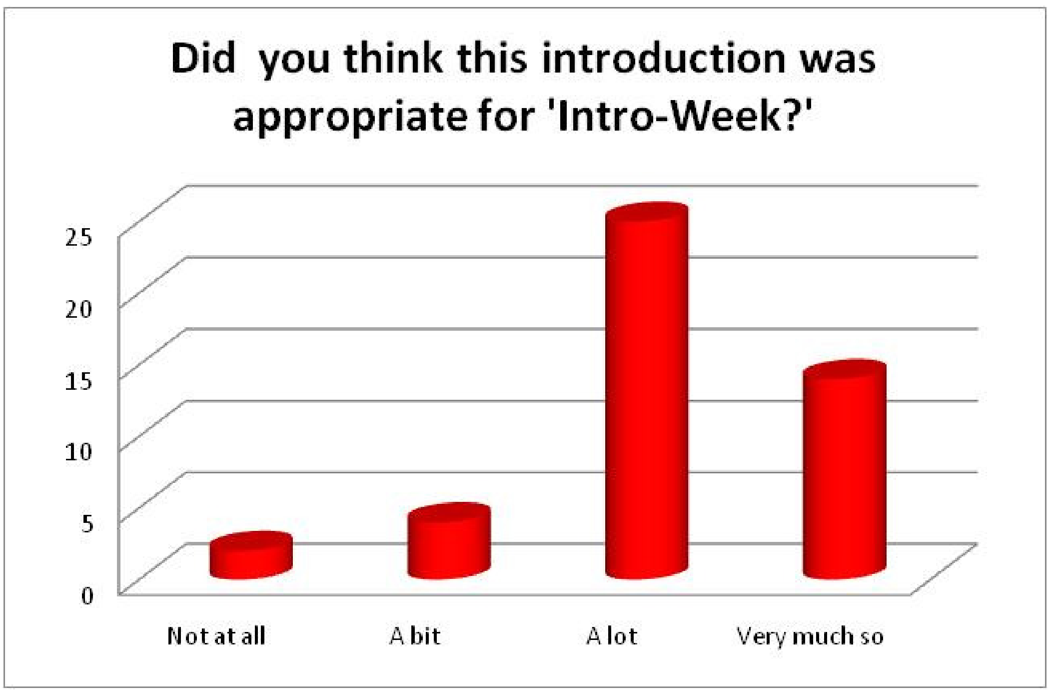


unstructured, people-oriented environments. Abstract Sequential Thinkers love the world of theory and abstract thought. It was also stressed that no thinking style was superior to another; they are simply different. Each style can be effective in its own way. The important thing was that students became more aware of which thinking style works best for them. Once one knows their particular style they can then analyze the styles of others helping them to understand other people better, making them more flexible and perhaps more effective.

Felder has published extensively among others on the use and validity of learning styles and his work provides a good summary of the work in the field (1988 and 2005). The work of Ammerman et al (2005), Sutliff and Baldwin (2001) and Larkin & Bundy (2000), further discuss learning styles relating them to technological subjects and psychological types respectively. Kellogg et al (2005) also provide useful insights in to the development of the complex thinking skills required by the global economy from today's engineers.

1.2 Skills Week

During Skills Week, the above theme was followed up in more detail and students completed a follow-up questionnaire (see Appendix 1) the results of which are shown graphically below:



In addition to the responses to the questions, the students made comments for the future direction of this 'Introduction to Teaching & Learning' exercise. A summary of their comments and recommendations are shown in Appendix 2. It is clear from the above graphs that although the majority of the students felt introducing the teaching and thinking styles as part of the overall Transferable Skills programme was useful, it is only natural that not everybody felt it neither changed their perceptions of others nor the way they approached their learning.

Marco Polo describes a bridge, stone by stone.
"But which is the stone that supports the bridge?" Kublai Khan asks.
"The bridge is not supported by one stone or another," Marco answers, "but by the line of the arch that they form."
Kublai Khan remains silent, reflecting. Then he adds: "Why do you speak to me of the stones? It is only the arch that matters to me."
Polo answers: "Without the stones there is no arch."

Now Kublai Khan no longer had to send Marco Polo on distant expeditions: he kept him playing endless games of chess. Knowledge of the empire was hidden in the pattern drawn by the angular shifts of the knight, by the diagonal passages opened by the bishop's incursions, by the lumbering, cautious tread of the king and the humble pawn, by the inexorable ups and downs of every game.
The Great Khan tried to concentrate on the game: but it was the game's purpose that eluded him. Each game ends in a gain or a loss: but of what? What were the true stakes? A checkmate, beneath the foot of the king, knocked aside by the winner's hand, a black or a white square remains. By disembodying his conquests to reduce them to the essential, Kublai had arrived at the extreme operation: the definitive conquest, of which the empire's multiform treasures were only illusory envelopes. It was reduced to a square of planed wood: nothingness….

Then Marco Polo spoke: "Your chessboard, Sire, is inlaid with two woods: ebony and maple. The square on which your enlightened gaze is fixed was cut from the ring of a trunk that grew in a year of draught: you see how its fibres are arranged? Here a barely hinted knot can be made out: a bud tried to burgeon on a premature spring day, but the night's frost forced it to desist."
Until then the Great Khan had not realised that the foreigner knew how to express himself fluently in his language, but it was not his fluency that amazed him.
"Here is a thicker pore: perhaps it was a larvum's nest; not a woodworm, because, once born, it would have begun to dig, but a caterpillar that gnawed the leaves and was the cause of the tree's being chosen for chopping down…
This edge was scored by the wood carver with his gouge so that it would adhere to the next square, more protruding…"
The quantity of things that could be read in a little piece of smooth and empty wood overwhelmed Kublai; Polo was already talking about ebony forests, about rafts laden with logs that come down the rivers, of docks, of women at the windows….

From Invisible Cities – Italo Calvino

2. SUMMARY

If some general conclusions are to be drawn from running the ‘Learning & thinking styles’ exercise as part of Intro-Week to be followed up during Skills Week, they could be expressed as follows:

- Students gave the ‘thumbs-up’, as far as the appropriateness of including ‘Learning & thinking styles’ as part of an Intro-Skills Week combination.
- A satisfactory first attempt; we are on the right track.
- Need to tweak the content to reflect the students needs and perspective.
- More hands on group or individual activities.
- Ensure the students perceive the connections and the value to be derived from this exercise.

A very interesting point is a comment made by one student that *‘it would be very useful if individual students received personal feedback on their learning/thinking styles’*.

Although a fairly reasonable demand, having to cater for 67 individuals on a personal basis (in the current cohort) would probably generate a lot of additional work for the person(s) responsible for this exercise. However, part of the value of what is being introduced must be that the students understand their styles and make full use of such understanding.

This work has been carried out as part of my own research in ‘Teaching and Learning’ over a period of nine years with my 1st year tutees, and up to now I did not have to formalise the process. Nevertheless, having now had the experience of running this scheme as part of the Intro & Skills week combination I can see that in order for the students to derive the full benefit from this process, the presentations must become much more focussed around the learning/thinking style questionnaires, to be followed by short personal feedback to each student. Efforts will also be made in order to increase the group activities provided as something explicitly preferred by the students, and as experiential learning is expected to provide the framework and the group work the catalyst in engaging the students in active learning as described by Holzer and Andruet (2000).

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APPENDIX 1

Follow-up Questionnaire on the use of Learning and Thinking Styles

1	2	3	4	5
Not at all (No)	A bit		A lot	Extremely (Very much so)

1. Did you find introducing you to your learning and thinking styles was useful? 1 2 3 4 5
2. Did the introduction affect the way you perceived yourself? 1 2 3 4 5
3. Did the introduction affect the way you approach your learning? 1 2 3 4 5
4. Did it have an effect as to how you perceived others? 1 2 3 4 5
5. Do you think it is appropriate that all 1st year students should be introduced to these concepts as part of their induction week? 1 2 3 4 5
6. Propose three things you would keep and three you would change in the introduction to learning and thinking styles.

1.	
2.	

3.	

APPENDIX 2

Students in their own words:

'Keep the survey; it is easy to fill and encourages students to reflect upon their styles'
'It is fine as it is'
'Expand on what each thinking/learning style means and how to take advantage of it'
'Thinking/Learning style questionnaires should be filled during intro week rather than given out to be returned during Skills Week; that way you will ensure that everybody gets the results back to you!'
'Would not change much. Make quiz compulsory'.
'Too much time between Intro-Week and Skills Week. Quiz should be done during intro-week'.
'More exercises!'
'I would keep everything to be honest! More questions and more details about thinking/learning styles; it was vey interesting!'
'Keep the enthusiasm (the presenter made me understand); add more real life examples'
'Give individual feedback to the students!'
'Keep questionnaires and group activities'
'Dr. Kapranos' approach was very helpful and informative'

ACKNOWLEDGEMENTS

The author would like to acknowledge the support of Claire Allam, Jane Spooner of Learning & Teaching Services (LETS) of the University of Sheffield for their support for this work through the Inclusive Learning and Teaching Project and Elena Rodriguez-Falcon, Director of Learning and Teaching Development (Inclusive Curricula), Department of Mechanical Engineering, The University of Sheffield for starting the ball rolling.

Cradle to? Introducing 'Environmental Issues' into the teaching of Engineering Materials

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Abstract: In a recent restructuring of subjects taught in the Materials degrees during the 1st year of studies at the Department of Engineering Materials of the University of Sheffield, it was decided to introduce a module that dealt with Environmental issues. The module was aptly named 'Cradle to? - Materials and the Environment' and was delivered to a class of 21 students through 24 lectures and 3 tutorial/problem classes in the course of a semester.
As a module with content very pertinent to current issues and prominent in the public arena and media, the course has received unexpectedly mixed reviews having run for the first time in 2009. The module somehow failed to capture the imagination of the undergraduates against the expectations of the members of staff that put it together. We look into the possible reasons of why this might have happened and propose ways to rectify the negative aspects as experienced by the students who took the module.

Keywords; engineering education, environmental issues, materials, sustainability, energy.

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1. INTRODUCTION

1.1 Environmental Issues and their Teaching in Materials Science and Engineering: Undoubtedly technological developments have been key factors in the prosperity that has been achieved and experienced by the developed nations over the last century. However, it has become apparent that humanity cannot continue on the extravagant usage of the finite material wealth of the planet, and that future prosperity and economic growth will be driven by developments in information technology, biotechnology and materials science and engineering, especially in relation to the environment. Furthermore, it is also clear that such developments must be not only sustainable but spread more equitably amongst all humanity.

Figure 1 gives a graphical representation of the major technological developments from the time of the Industrial Revolution of 1770's to the present as well as hazarding a guess as to the possible forthcoming technological wave to involve bio-technology, aerospace and environmental technologies.

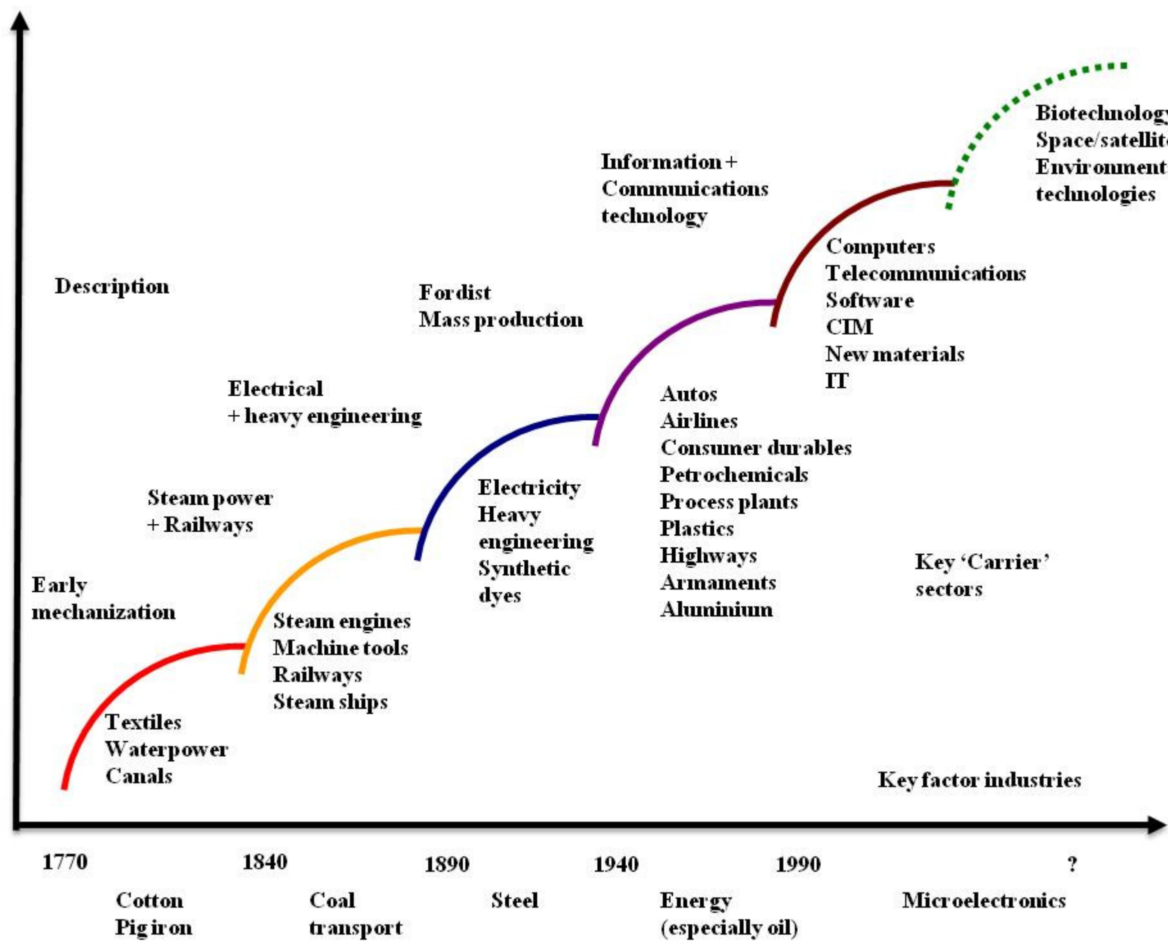


Figure 1 Technological waves of revolutionary development originally proposed by Schumpeter as adapted by Dodgson (2003)

The three parts of Figure 2 show some worrying trends: the upper graph shows carbon dioxide (CO_2) concentrations (in parts per million) for the last 1100 years, the middle graph shows (on a logarithmic scale) the history of UK coal production, Saudi oil production, world coal production, world oil production, and (by the top right point) the total of all greenhouse gas emissions in the year 2000. All production rates are expressed in units of the associated CO_2 emissions. The bottom graph shows (on a logarithmic scale) some consequences of the Industrial Revolution: sharp increases in the population of England, and, in due course, the world; and remarkable growth in British pig-iron production (in thousand tons per year); and growth in the tonnage of British ships (in thousand tons). In contrast to ordinary graphs, the logarithmic scale allows us to show both the population of England and the population of the World on a single diagram, and to see interesting features in both. The graphs leave no doubt that we have been on a steep climb in all of them and continue to do so in most of them, MacKay (2009). These trends leave no doubts that humanity needs to change the way it treats the planet and many of the people who inhabit it. For millennia, mankind has had an ever increasing need for energy initially relying on heat from the sun and biomass as food and firewood, the use of other animals as agricultural labour, harnessed the power of moving water, and the winds but until this point our use of energy had been largely sustainable—with the possible exception of excess forest cutting—and our impact on the planet was only of a local nature. The industrial revolution's requirement for much larger amounts of power in locations far from any natural resource necessitated a radical change. Fossil fuels (first coal, then oil) proved ideal for providing this power. Unfortunately the emissions from their use have altered not only the local environment but the atmosphere itself, and the concentration of carbon dioxide has risen from 280 parts per million to 370 today—a level unknown for millions of years. Because carbon dioxide acts as an insulator, this has slowly warmed the planet, in turn melting ice and raising sea levels (Figure 3).

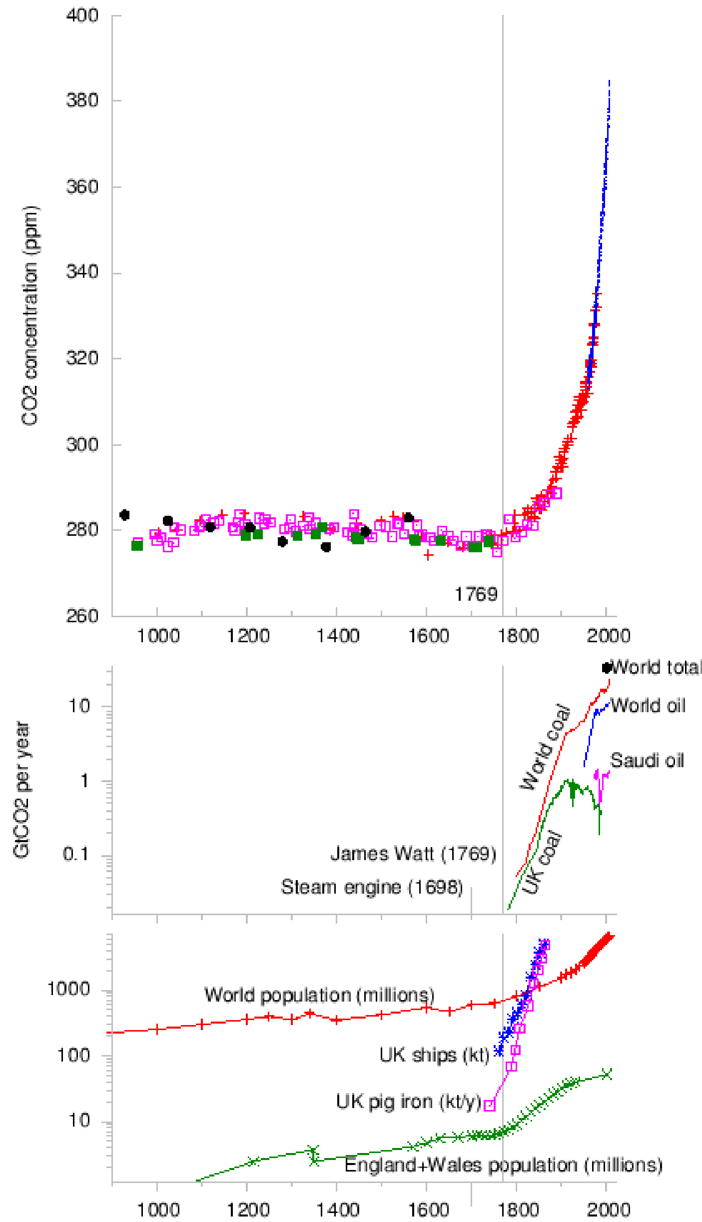


Figure 2. Trends of CO_2 , World population, and production of fuels from the time of the Industrial Revolution to the present MacKay (2009).

It has taken us a long time to realise the seriousness of the situation. The basic phenomena and its consequence were first described in 1859, and now terms such as global warming and climate change appear regularly in the media and political debates. For any degree of equality humanity needs to be using more energy, not less. Yet failure to reduce our emissions of greenhouse gases will lead to a level of climate change that will affect the wealth and survival of many of the poorest people on the planet and harm the economies and landscapes of the wealthiest. The only sensible solution would appear to be that we use energy more efficiently in the short-term and that we give up our reliance on fossil fuels in the medium term.

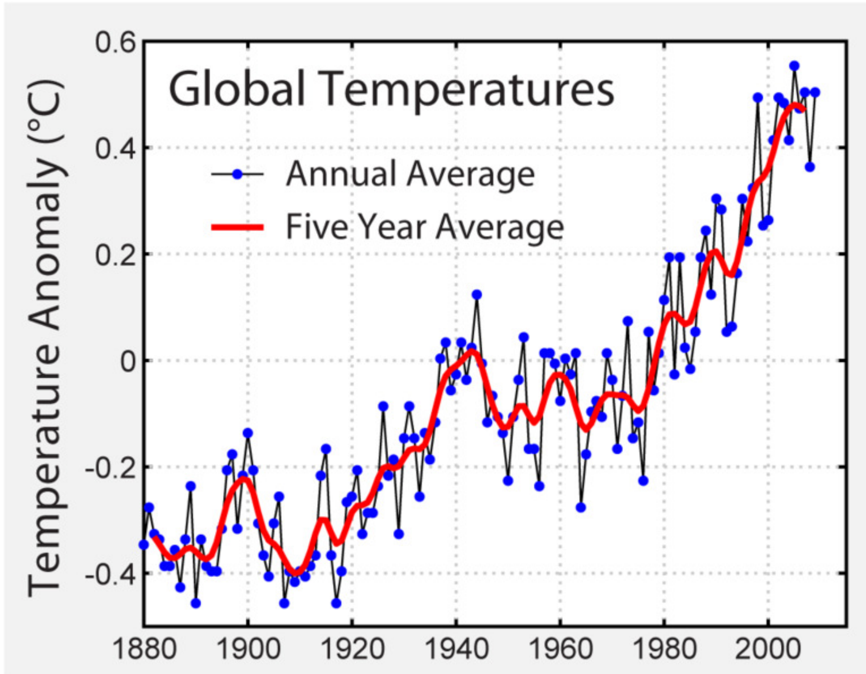


Figure 3. Trends in mean temperature variations over Land & Ocean since 1880 (http://en.wikipedia.org/ wiki/Temperature_record)

Ashby (2004) discussing materials and product design states that: "Good design works. Excellent design also gives pleasure. Materials, are the foodstuffs of design, and processes the ways of preparing the materials for consumption. You don't need new materials to create exciting new designs. The element of satisfaction is central to contemporary product design. It is achieved through an integration of good technical design to provide functionality, proper consideration of the needs of the user in the design of the interface, and imaginative industrial design to create a product that will appeal to the consumers at whom it is aimed. Materials play a central role in this. Functionality is dependant on the choice of proper material and process to meet the technical requirements of the design safely and economically. Usability depends on the visual and tactile properties of materials to convey information and respond to user actions. Above all, the aesthetics, associations and perceptions of the product are strongly influenced by the choice of the material and its processing, imbuing the product with a personality that, to a greater or lesser extent, reflects that of the material itself. Consumers look for more than functionality in the products they purchase. In the sophisticated market places of developed nations, the "consumer durable" is a thing of the past. The challenge for the designer no longer lies in meeting the functional requirements alone, but in doing so in a way that also satisfies the aesthetic and emotional needs. The product must carry the image and convey the meaning that the consumer seeks: timeless elegance, perhaps; or racy newness". One Japanese manufacturer goes so far as to say: "Desire replaces need as the engine of design".

Although this is a beautifully written essay on the crucial interplay of design and materials, today's experiences make it imperative that our design concepts move with the times, i.e. as the work by Lagerstedt (2003), it is stated that ''Design for the Environment is also known by numerous other names such as: Green Design, Eco-Design, Sustainable Design, Environmental Conscious Design, Life Cycle Design, Life Cycle Engineering and even Clean Design''.

2. THE COURSE

The content was divided into three main areas, each to be undertaken by a different member of staff. The subjects were delivered using traditional delivery modes of teaching and each section was supplemented by a 3 hour tutorial session.

2.1 Energy balances and Energy cycles: Energy & Materials, Energy usage in a modern economy, Energy and the environment, The Greenhouse Effect, Materials and energy conservation, Materials and energy production: the case of solar power, Materials and the Environment- mining and extraction, Measuring the impact, Materials and sustainability.

2.2 Energy and Materials: two case studies: Producing goods, Production of Aluminium, Production of Steel, Transport, Market size, PET production, Natural Gas.

2.3 Life Cycle Assessment: Setting the scene, Materials and the Environment, Prerequisites to Life Cycle Assessment, The Materials Life Cycle, Eco-attributes of Materials, Eco-informed Materials Selection, Examples, Materials for a Sustainable Future. Recommended book: Materials and the Environment, Eco-informed Material Choice, Ashby (2009).

Although it was clear that there will inevitably be some repetition of the various concepts included under the three headings, it was felt that: a) this is not a bad thing to have as it helps with consolidating understanding and b) as each area was delivered by a different member of staff, there will inevitably be a different perspective brought into play, which is also not a bad thing to have when introducing such systemic concepts.

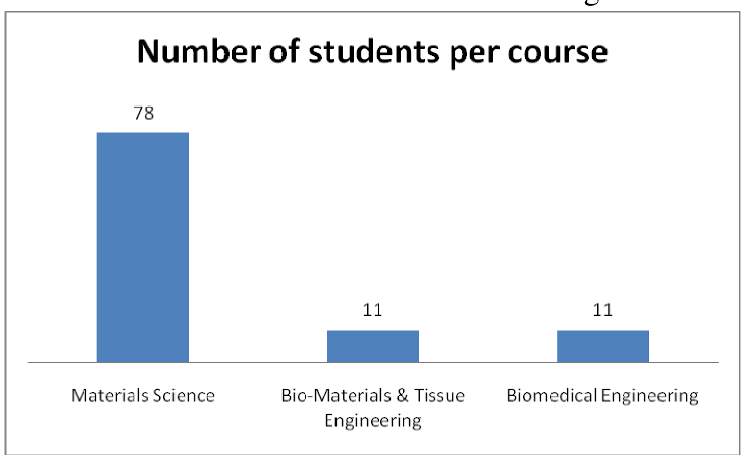
As well as the individual assessments based on the problems classes (worth a total of 20% of the marks) the students were required to undertake a group project (worth 80%). Each group was to investigate the lifetime materials and energy flows for the item given against that group's name. Their findings were to be presented as an A0 laminated poster prepared using Powerpoint. The posters should be produced in electronic form and then sent for printing. Guidelines for producing their posters were available under MAT1920 on Muse. The posters were to be assessed at a poster session, when all students were required to be present to answer questions relating to each poster. In addition to the poster, each group should also produce an agreed statement assessing the contribution of each member of the group to the project. Finally each person should each produce a short (maximum 1000 words) report summarizing the aspects of the project that they worked on.

The actual problems classes were exactly what is denoted by the title; problems classes with students having to perform calculations or write short essay type answers to various questions.

This part of the module it was to provide both a forum for the students to engage with what had been said in class as well as demonstrate to the member of staff responsible that they had engage with the subject.
The author, having discussed the module with the students decided to change the content of his part of the module as follows: Lectures: 1. Setting the scene, 2. Energy revisited, 3. Taking another look at design, 4. The materials Life Cycle, 5. Sustainability issues, 6. Looking at another discipline 'city planning, urban design, and these types of 'fuzzy' ideas that help govern community quality of life' – (Prof. Marc Schlossberg, University of Oregon), 7. Sustainability, the Gripple Way (Gripple Ltd), 8. Eco-informed Materials Selection.
Problems Class: Groups were given a sub-assembly made of component parts and were requested to: 1) Draw and complete a streamlined LCA matrix for it, 2) Draw a life cycle diagram showing an inventory compilation, and 3) Re-design the part to be more eco-friendly and give your reasons why you think it will be so. The total report to be submitted should be no more than 3 A4 pages.

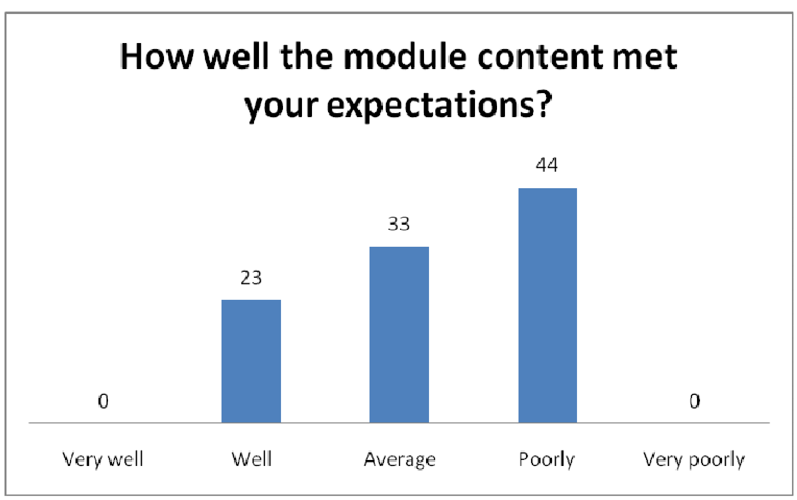
3. THE RESPONSE OF THE STUDENTS

The group of 1st year student that took the module was a mix of three Materials degree streams as shown in the adjacent figure.



The students' overall response was positive, although not very forthcoming as only 44% of the total were involved in the feedback. However, a number of points were raised that require further attention.

3.1 The content:
Subject too dry. Module should be optional as it is not as essential to 1st year students as other modules are. The same information repeated over 24 lectures! Too much data. Lectures very similar. Need more variety. Problem classes need to be longer. Problem classes good although a little tedious!

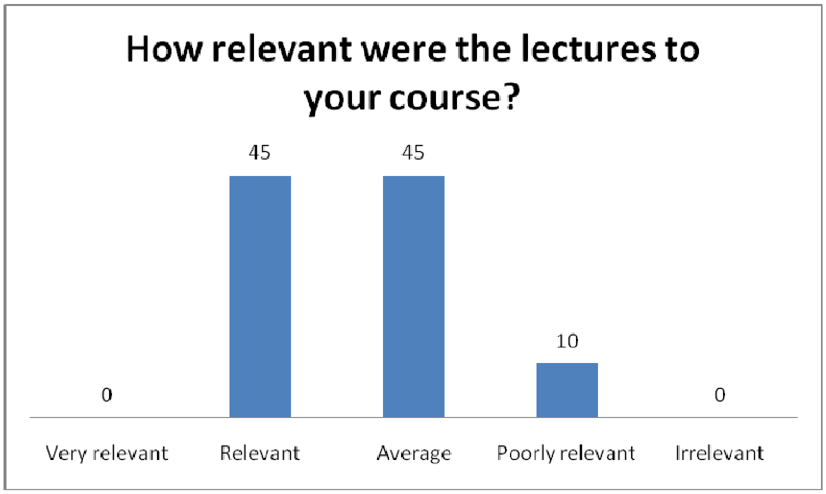


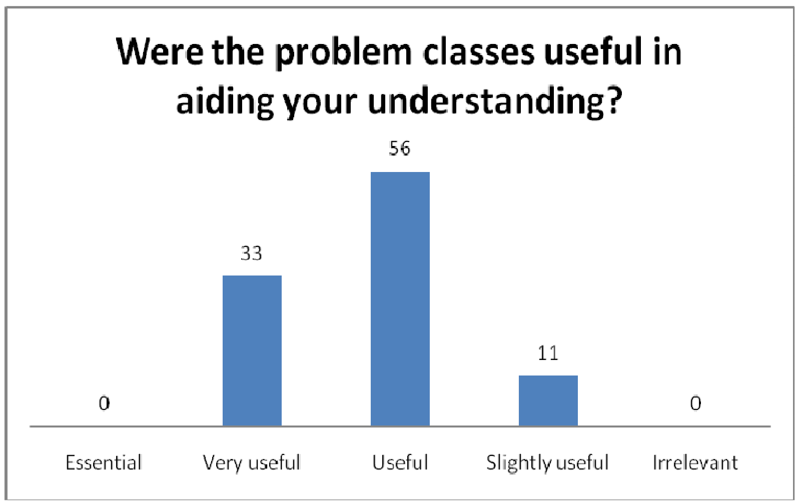
3.2 The assessment process:
The assessment could have been done better with smaller units throughout the module rather than one big project at the end.
Final group project work responsible for most of the module marks.

3.3 The practicalities:
Time tabling has effect on

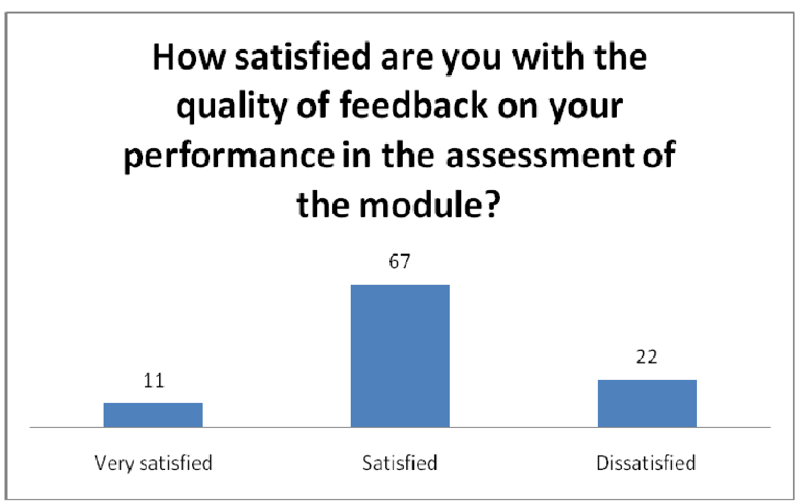
attendance (mounting work load towards the end of year meant that it was not worth it to wait for 3 hours when a piece of work is due in the next day!)

It is clear that the linkage of this particular module to the rest of the course materials was not made explicit to the first cohort of students, although it might have been obvious to the educators. From a delivery point of view, the module delivered what it set out to achieve, i.e. make the students aware of the issues and provide them with the factual information that will allow them to make informed choices. However, the module failed to excite and engage them. Why?





Could it be that we used a 12th Century model for teaching the engineers of the 21st century, Felder (2006). Was it a case that we did try to tell them too much rather than actively engage them in the process? There is no doubt in our minds as educators that for students to learn in a meaningful manner they must be actively engaged in the learning process but what stop us achieving it? Is it a case that the time available to educators in HE establishments to achieve all that is asked from them leaves them no opportunities other than being adequate? I do not doubt that we are all fully committed and concerned with the well being and learning of our students but becoming outstanding teachers in today's University teaching environment is not easy; maybe it never was.



Being a world-class researcher is a full time job in itself, as is being an exceptional teacher. Add the increasingly

bureaucratic nature of academia, the extra administrative duties, compounded with increasing pressures because of the current economic state of affairs demands staff reductions and it becomes easier to see why we might have failed to actively engage and excite our students. After all we are only human and there is such a thing as work overload.
Nevertheless, there is a need to balance the various demands made on us and ensure success with the equally important tasks of research and teaching. Maybe we do require some support to achieve that and it might involve major attitude adjustments by our employers and ourselves; they have to provide the resources in recognition of our considerable efforts and we have to ensure that we are not just going in and giving good lectures but we use the various innovative educational methods available to us. Maybe it is time to re-evaluate the publish or perish syndrome that pervades our research activities over that of the intellectual curiosity in the hope of improving society as well as the well and tried teaching methods set against those involving some loss of control to the students. Of course not every student will subscribe to this approach and once again all our teaching experimentations must be tempered by a delicate balancing act; 'Μετρον Αριστον' – loosely translated 'everything in good measure is perfection'.

Having just completed the delivery of this module for the second time to a new cohort of students using the new structure outlined earlier in section2 as well as the input of two outside colleagues (one from industry and one from another discipline) the students reaction has been very positive. They showed much better engagement with the subject and they appreciated the external points of view that provided the connections on systemic and interdisciplinary approaches. Finally the 'hands on' problems class seems to have brought everything talked in class together, as well as providing for the different learning styles in a class of would be engineers.

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ENTREPRENEURSHIP & INNOVATION IN MATERIALS ENGINEERING

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Abstract: Having developed a module on Creativity, Innovation, Enterprise and Ethics that reflects the continuous drive to educate the all round engineers highly sought after by employers and run it over nine years, we have collected enough evidence on both the validity of such efforts as well as their effectiveness in achieving their goals.
This paper summarises the cumulative experiences of developing and running this module over the years and discusses possible future directions.

Keywords; engineering education, creativity, innovation, enterprise, ethics, personal development.

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1. INTRODUCTION

1.1 Course concept

The course, originally denoted as module MAT388 'Creativity, Innovation & Entrepreneurship' evolved out of the perceived need to close a knowledge gap that appeared to exist in our engineering materials graduates regarding to the commercial side of engineering design, Kapranos (2008). Materials are what designers use to create their various artefacts and it would be true to say that most of the dramatic developments in engineering materials over the last century have been the result of scientific research. However, it would be equally true to say that for every pound spent on science driven research, over the same period of time, a much larger proportion was spent on research driven by specific market needs.
Figure 1 shows an adapted simplified analysis of the various drivers behind product design proposed by Fields et al (2001) that despite its simplification serves as the basis for the perceived need for creating the above module. Of course it was felt that there is another important point the module should address in order to complete the development of our graduates was the development of the 'self'. As engineers and scientists they must be aware that apart of the knowledge and expertise they will take with them into their chosen professions, they will also inevitably carry with them their personalities, their values, beliefs and attitudes and these can have a major effect not only on their design approach but on the correct execution of their professional duties. For that reason, ethics in scientific research and science were included as

part of the module and hence the slightly final long winded title: 'Creativity, Innovation, Entrepreneurship and Ethics'.

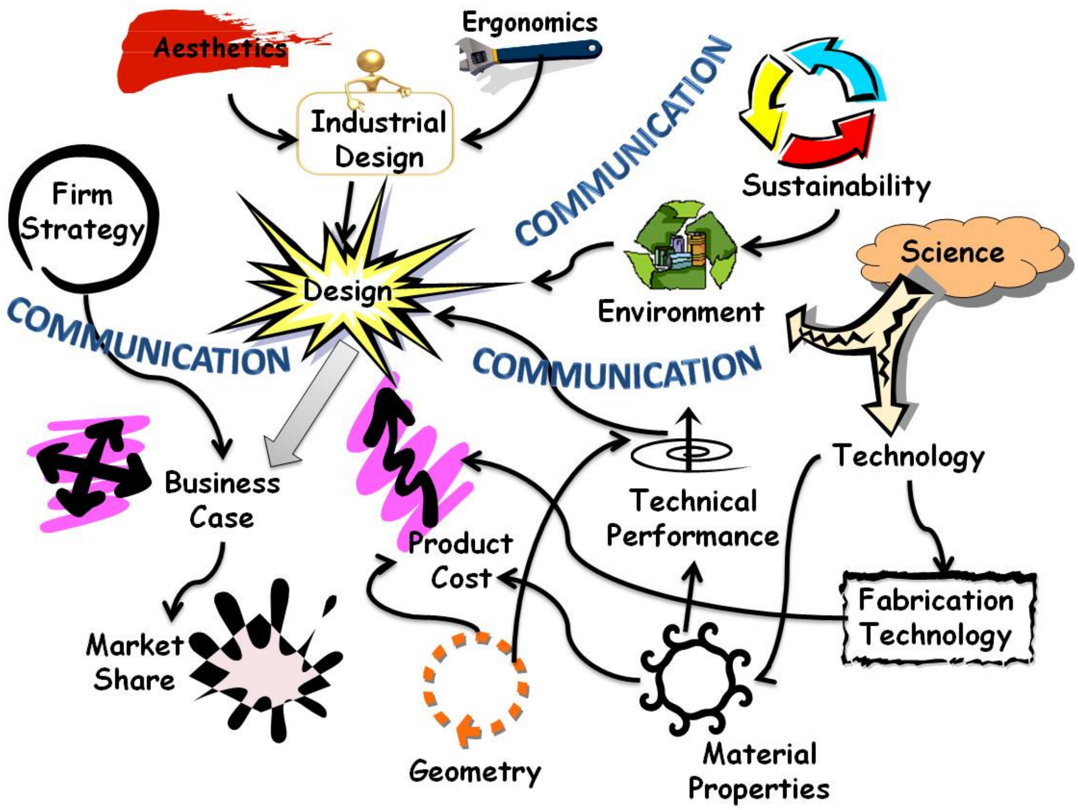

Figure 1 Driving forces that influence product design, including the very essential communication between people [adapted from Fields et al (2001)

1.2 Course development

The module has run over nine years with continuous modifications and improvements both as far as content and delivery were concerned. The need of realization by the students of the complexity involved in engineering decision making due to the multiplicity of objectives and of course materials available to them required the introduction of topics such as Decision making, Behaviour in Organizations, Leadership, Motivation, Conflict, Negotiation, and Project Planning. In addition, Quality Control, TQM and Project Appraisal techniques also found their way in becoming part of the module together with the basics of financial and management accounting and costing.

Of course, immersing the engineering students in such concepts is neither easy or popular with all of them and care has been taken to embed these topics through a combination of group case studies and the use of external lecturers that can bring them into focus through industrial applications or professional expertise, e.g. use of a Pattern Attorney, Special Projects Manager, Director of Policy Planning, etc.

Although the changes in content have fluctuated within certain boundaries limited by the curriculum, the teaching methodology has been more flexible allowing the transformation of the module from one of a 'lecture heavy' mode to one of 'inquiry based learning', giving students much more active participation in their learning experience, as well as empowering them to broaden their communication, group work and presentational skills as part of the continuous assessment format of evaluation. The suitability of inquiry based learning has been debated by many and Perrenet et al (2000) give a good summary of the debate.

The course is based around lectures on the themes outlined above supported by short class problems/cases interspersed throughout the module. The assessment is in continuous format and it is based on mini-case studies, for example where the students have been given some 'seed funds' and have to go away and increase their capital over a period of a week, or the development of a business plan in prescribed markets, group presentations and a final individual portfolio where each student expands on their own particular take of the complete module. The structure and presentation of the individual portfolio is purposely kept flexible in order to bring out the creative aspects of the students as well as their own interpretation of the subject matter discussed over the series of lectures and discussion sessions.

Although this approach reflects the creativity ethos of the module, it has the drawback of consistency in assessing the individual contributions. A balance has been struck by setting out the various areas that students must address in their portfolios whilst still providing them with individual choice of how it is done; 'show them the mountain to climb without specifying how they actually do so'. Admittedly the assessment system is far from perfect but in the main allows both individual creativity and group performance to be looked at.

The group experience in inquiry based learning of the students is what they seem to have appreciated more than anything in this module. Being thrown into a 'money-making' exercise from early on and finding out how to do it themselves successfully and within legal restrictions, quickly brought up a number of issues that were then looked in more detail and discussed in class.

Furthermore, the continuous use of group work with all its associated issues acted as a focus, bringing to the fore such topics as motivation, conflict, negotiation, leadership, decision making, for class discussion. This direct relationship of coupling personal experience, derived through the group process and associated information handed out in class became a powerful learning tool; so much so that it has already been planned that every topic covered in future modules will be based on group cases supported by handouts and short Powerpoint presentations.

Finally, the use of *'experts'* is another learning tool that has been used successfully and will continue to be part of this module. Students react positively in seeing real applications of the knowledge being discussed in class delivered by persons who are experts in a particular field, be it a patent attorney discussing IP issues of innovations or a Psychologist discussing behaviour in Organizations.

1.3 Student responses in their own words

Of course it would be easy to sing the praises of ones personal work but the voices that matter should be those of the students themselves, including voices of dissent or dissatisfaction:

'This module is a welcomed break from the usual engineering subjects...it brings a new perspective about the world of business, how to manage myself and deal with others...the knowledge gained will be carried into my working life and beyond'

'The module covered not only creativity, innovation and enterprise but psychology, philosophy and personal character capabilities.... I now have a better understanding of myself, human nature, human behaviour, the way people think, and how to deal with people...'

'Although the module may have been necessary for the more narrow minded engineers, I never find myself stuck for ideas or inspiration...I found the management terms and strategies totally uninteresting and hugely patronising...'
'I especially enjoyed the good atmosphere and diversity of the class...the group projects and presentations were a wonderful experience...'
'I feel I have gained something from this module I couldn't have gained from others...I feel I have become a better person and engineer in some ways...I think the module has made us all better engineers...'
'I know one thing that I know nothing, Socrates...once you embrace this mind set you are free to learn all you could possibly learn...realising you know nothing allows you to see things for the first time, with an open mind, no pretences, nothing taken for granted, nothing is too obvious any longer...'
'It is difficult to produce a module that will satisfy every student...there were parts of the module I would like to see removed, the statistics for instance, however other students may find them relevant, interesting and important...'
'I thought the group exercises were a great learning experience because of what they involved, working in groups, finding things for ourselves and standing up to present our cases...'
'The whole series of lectures has given me much cause for thought...the lectures on ethics were excellent...'

*'**Good points**: well rounded module, interesting topics, subjects covered useful for the future, generated lots of enthusiasm, especially the group work and presentations, relaxed lecturing style helped the learning experience, good range of speakers, clear and straight forward assignments...*
***Bad points**: Few irrelevant topics for engineers, some speakers had poor communication skills...*
***Recommendations for the future**: more group work, more mini-projects in class.'*

'I was pleasantly surprised with the first in this series of lectures...as opposed to numerous other lectures the atmosphere was much more relaxed and opened the floor to a different type of thinking rather than just plain note taking and learning facts...'
'This module turned out to be an interesting module; it has made me think about myself and what I want from my career...it has also helped me to identify some of the areas I need to work on to improve myself...'
'This module has been a rewarding experience...I hope it will remain the staple of the 3rd and 4th year undergraduate course and with its enthusiasm and applied innovation continue to inspire students to greater things...'
'I have enjoyed creating the personal portfolio...I have put thought in every single page to make it interesting and used my creativity to present it in a different way...I hope the readers can have as much fun reading it as I had making it...'
'My favourite guest lecturer was on communication...a priceless lesson...'
'I found the guest lecturers unnecessary and dull with one exception...the one on transactional analysis...truly inspiring... I even bought the book today...'
'I approached this portfolio in a manner which maintains the overall theme and vibe in the class room; colourful and energetic...'
'This module proved to be a great journey...I greatly enjoyed the course...don't worry about the destination just enjoy the travelling, take life as it comes...an excellent moral that I intend to follow...'
The personal portfolio is creative for me because it is representative of my personality and has been created by my inner self...similarities between myself and the portfolio: well organised, thorough, full of information, unique and full of positivity...'
'Creativity cards...an excellent idea that I will definitely be using in the future...'

'The group tasks became the most enjoyable and most challenging aspect of the module…they enabled me to apply what I learned in the lectures…perhaps the most important lesson is that there is more to management than meets the eye…'

1.4 Worried colleagues & Negotiations

Once again, trying to live up to some basic tenets of good teaching, i.e. *'if we want students to learn we must capture their attention', 'the more you can provide them with a framework to interpret the material being taught, the easier they will understand new ideas', 'don't overload the system'*, and having gone down the unpredictable road of power sharing with the students, there were occasions that colleagues and sometimes students were left bemused by the slightly unorthodox, even chaotic proceedings.
In addition, having chosen that the module would be continually assessed, with no conventional written examination at the end of it, created both challenges and opportunities to try different things in motivating the students, i.e. competition between groups, prizes as well as individual portfolios relating their experience of the module in their own words.
What follows are examples of communications between the module leader and various colleagues and students during the latest module completed in December 2009.

Dear Plato
I have seen the surveys for lunch deliveries to staff produced by students which are, I think, an exercise for your module. They are then going on to deliver lunches they have made for a week. Forgive the obvious question, but has someone looked to see whether there are any Health and Safety issues connected with this - does this activity come within the HSE rules for selling food since they are being paid for it.
Yours , John

Dear Dr Kapranos
I've just had a visit from some students on a money making project from one of your courses? Before I parted with my cash I wanted to check that the proceeds were going somewhere other than yours or the students pockets! Which is what the students seemed to think? Have you got a charity lined up?
Cheers, Colin

Dear Colin,
This is a group project on a money making scheme as part of the Innovation & enterprise part of the module.
Originally I had in mind a charity. However, as I have already parted with £40 of my own cash which I used as 'seed funds' for the group exercise, I hope that I will get my own money back (although not guaranteed) and then discuss with the students what to do with any profits if there are any.
The module also includes ethics so we will see what happens.
Regards, Plato

Good luck.
Ethics and business? That sounds very challenging!
Colin

Hi Plato,
At Staff-Student committee on Weds the 3rd year BME rep raised a couple of issues regarding MAT388. Firstly there were some complaints about the perceived workload and secondly there

were some issues regarding guidance as to what was required for the CA submission. The first issue is probably just down to timetabling, with your module competing with BME projects, MAT372 'Group Projects in Bioengineering' and MEC305 'Engineering Management' for their time in Semester 1. Flicking through the timetables of the various cohorts who take your module it does certainly seem that BME have quite a crowded timetable, with 12 free slots per week compared with between 19 and 28 for some others. The only other cohort with a similar lecture load is BEng Aerospace Engineering, with 13 free slots per week. I haven't heard of any issues from this cohort but then there are only two students as against 19 from BME. Obviously we don't actually need to change anything if you don't think it appropriate but we need to show that it has at least been considered.

Hi Plato,
after discussing the sponsorship of your presentations with the team and finding out from Omolade what last year's winners received, a £10 voucher, we are happy to match this and provide the funds for a £10 Amazon voucher for each individual in the winning team.
As you will not know how many people are in the winning team until on the day it would be best for us to transfer the funds once the winners have been announced so you can purchase the vouchers.
University of Sheffield Enterprise has certain targets to hit, two of which include business plans developed and individuals advised and engaged. Therefore, are we able to take copies of the businesses plans produced by the teams? All information will be kept confidential! We also need to evidence the people involved in the activity we are funding, this would simply involve the students signing in on a sheet we produce. Tracey and I would get the students to sign this so there is no additional work for you.
Does this sound OK to you?
Many Thanks, Sarah

Hi Plato,
Yes, we are happy to sponsor the winners at £20 each. Are we able to have copies of the business plans?
Many Thanks, Sarah

Hi Plato,
Thank you for allowing Tracey and I to judge the presentations on Friday, we really enjoyed listening to the great ideas and were very impressed.
I have attached a couple of photos for you, although they are not the best quality. As we discussed, it would be great if you could either pop copies of the business plans on the internal post or I will call over and collect them. Thanks
Sarah

Dear Dr Kapranos,
we are very pleased that we won today, Rahma told us that one of judges suggested that we could apply for funds to actually start up such a business. I personally think this would be a great opportunity, and would be fantastic to have it in our CV. I was wondering if you can help us to get in contact with her, or advice us in this matter.
Thanks for your great lectures this semester
Best Regards, Atra Malayeri

Excellent, if any of the groups want to take their ideas further put them in touch with us. Have a great Christmas.
Sarah

2. DISCUSSION

2.1 General comments

Teaching a module which in the majority has a non-technical content to students of engineering is an interesting challenge and this challenge is especially enhanced when the students are on their final year of studies. The thinking for positioning such a module in the later years of undergraduate studies was based on the fact that the students have to develop a thorough understanding of the scientific/technical aspects of their chosen field of expertise before they could start making the appropriate associations with extraneous subjects such as management, innovation, enterprise and ethics. However, this logic has a number of drawbacks, one is that these subjects, as can clearly be inferred from Figure 1, are not extraneous but in fact they are an integral part of engineering design, and of course it goes without saying that exciting design that will help society through the various predicaments we are currently facing as a species will only come through creativity and innovation. Another drawback is that if the students are allowed to arrive towards the last year of their studies without even the rudiments of awareness of these topics, then it will require a great amount of creativity in the part of the teachers to first engage the students and then work through the various mental mind sets that have been formed; as can be seen in some of the examples of *'students in their own words'*, above. Furthermore we are making the assumption that first year undergraduates are not capable of making the necessary connections early one in their course.

It appears to me that the educators are following their own mind sets in making these assumptions and it would be more appropriate if we expect our young undergraduates to be part of the solution to the problems of sustainability, they must learn early on how to think systemically and consider the whole rather than only the sum of its parts; it is not a case of either or is a case of both used in balance as appropriate. There are conflicting issues there but these have to be emphasised and resolved early on rather than left to be dealt with as an after thought. The work of the engineers is in continuous tension in creating the things of tomorrow with the technology of today, if not the technology of the past. There is a balance to be had between working with what is within our grasp and things that are beyond our reach. There is always a risk involved when you reach out further than your grasp but risk has always been part and parcel of engineering design. Engineers have always taken risks but they like to think that these risks are based on knowledge and probabilities and as such there will always be faced with failures of their creations. However, it is very important that they learn from their failures and use their failed experiences as guides for future decisions as technological evolution is based on conscious choice rather than natural selection.

2.2 Comments on module MAT388

Material Engineers must be knowledgeable of the basic facts of their profession. However, any profession has a number of further characteristics associated with it:

- Requires specialized knowledge
- Requires considerable preparation in skills, methods and principles
- Requires maintenance of high standards of achievement and conduct
- Requires engaging in life long learning and public service

Here is an example taken from the Code of Conduct 1989, The Institute of Materials (UK).

Public Interest: Members shall do all in their power to ensure that their professional activities in no way put at risk the health, safety or welfare of any person or expose property to the risk of destruction or serious damage. In addition, members shall have due regard for the need to protect working and living environments and the need to ensure efficient use of natural raw materials, reserves and resources.

So clearly our graduate engineers must supplement their specialized learning with other skills, communication being a very important example. They have to be aware that in the final analysis in whatever we do for a living we will deal with people; it will always be us and them! Therefore, a good starting point would be to know who we are, what makes us tick, what we believe in. This personal knowledge is very important if we are to follow the code of ethics of our chosen profession. There were always ethical conflicts and there will continue to be so we must be aware of where do we stand as a person in relation to the multitude of issues that will face us and challenge us as engineers.
As it can be seen from the points raised by the students themselves, it is impossible that any module we create will be equally interesting to all, as educators we can only do so much and no more. However, if we accept as a model that education is not like transferring water into an empty vessel but rather the analogy of going on a journey, then we can see that this module has gone a long way down the road of making the students part of the exploration, setting ports of call as targets without marking out the exact route to be taken in the hope that the students both enjoy the journey and gather a lot of knowledge on their way.
As a module on creativity amongst others, I strongly emphasise the aspect of *'fun'* as an antidote to stagnation of ideas which comes from our fears; especially for students the fear to be heard and the fear to be seen as being different. In future, therefore, there will be continuation of the parts enjoyed by the students, such as group work and case studies, and re-structuring of the parts they found harder to engage with in more inquiry based learning approaches.

In closing, I would like to think that the module goes some way towards the vision of the Renaissance Engineer by Dahms (2001): *'Broad minded, ethically and ecologically responsible agent of social and material change towards a socially just and ecologically sustainable world'*

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PEER-ASSISTED TUTORING IN CHEMICAL ENGINEERING - DEVELOPMENT OF A TUTOR-ORIENTED MODULE

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Abstract: A system of peer-assisted tutoring was introduced to the curriculum for a 4-year, professionally-accredited degree programme in Chemical Engineering. The system involves small-group, peer-assisted tutorials (PATs) associated with specific modules. PATs were initially developed to support a core 3rd Year module in Unit Operations. For the initial pilot series of PATs, Tutors (4th Year Chemical Engineering students) were remunerated for their efforts. The PATs provided Tutees (3rd Year students) with structured opportunities to work together, solving lecturer-defined, course-related problems, facilitated by slightly senior (4th Year) students. Tutors received training in directed-questioning and group facilitation and were supported with the relevant course material. The pilot series of PATs was positively received by Tutors and Tutees, with definable benefits for both groups. Based on the success of the initiative, a 5-credit elective module (CHEN40430: 'Peer-Assisted Tutoring in Chemical Engineering') has been developed for 4th Year Chemical Engineering students. For this module, the PATs system has been expanded to include another core, 3rd Year module, in Computational Methods, where PATs are implemented as computer-based sessions. This paper reports on the development and initial implementation of the Peer Tutoring module, with specific reference to Tutor-based elements and to Tutor experiences. Tutors reported improved understanding of the relevant engineering principles, increased confidence in group facilitation and a sense of satisfaction in supporting others in their learning. There is potential for implementation of the system in other Engineering curricula.

Keywords; peer-assisted learning (PAL), peer-assisted tutorials (PAT), Chemical Engineering, transferable skills.

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1. INTRODUCTION

1.1 Background

Engineering graduates are primarily valued by employers for discipline-related knowledge and for their ability to put that knowledge into practice. However, effective engineering practice depends upon an additional set of more generic, or so-called 'transferable' skills. In reviewing employer expectations of graduates (regardless of discipline), Archer and Davison, (2008) reported that employers prioritised communication and team-working skills. The relevance of such skills for engineering graduates is recognised by professional accreditation bodies, including, for example, the IChemE (2005). Crucially, these skills must be 'developed and integrated in an appropriate way', within the curriculum, within designated broad areas of study, including 'core Chemical Engineering'. This paper describes work undertaken at UCD, within the framework of a 4-year honours degree programme in

Chemical Engineering (accredited by Engineers Ireland and, at Masters level, by the IChemE) on the development and implementation of a senior-level elective module. The module, 'Peer-Assisted Tutoring in Chemical Engineering' (known hereafter as 'the Peer Tutoring Module'), is designed to facilitate students in developing relevant transferable skills, in a discipline-specific context. For a system of Peer-Assisted Tutorials (PATs), associated with two, core, 3rd Year Chemical Engineering modules, students enrolled in the Peer Tutoring Module act as Tutors to small groups of 3rd Year students (Tutees). This paper focuses on the structure and delivery of the Peer Tutoring Module and on the experiences of the students (Tutors) enrolled in it, when first offered, during the Spring semester, 2009-10.

1.2 UCD Pilot Study of Peer-Assisted Tutorials

PATs may be described as a system of 'learning from others'; other such systems include peer-assisted learning (PAL) (e.g. Fleming, 2008) and supplemental instruction (SI) (e.g. Stone and Jacobs, 2006). PATs were first introduced to UCD in a 2008-09 pilot study, which is described elsewhere (Kieran and O'Neill, 2009). Briefly, PATs were implemented in the context of a core module for 3rd Year Chemical Engineering students (CHEN30020: Unit Operations). For the PATs, the 40 students (Tutees) enrolled in the Unit Operations module were allocated to groups of 5-6, with a single 4th Year student assigned as a Tutor to each group for the duration of the semester. The Tutors, who had volunteered for this work, were modestly paid. During the 12-week semester, there were 6 PATs. Examination-type questions were assigned as homework for each PAT, with 10% of the module grade allocated to Tutee attendance, participation and individual effort on completion of homework. The role of the Tutor was to facilitate the group in collectively addressing the assignments, rather than to teach the students or to simply provide the answers. Tutors were required to participate in a 2.5-hour training session, addressing the principles of PAL and PAT; the structure of the PATs; the role, responsibilities and expectations of the Tutors; techniques for supporting teams in solving problems; directed questioning (Jones, 2007); group facilitation.

The PATs exemplified several of the well-established 'seven principles for good practice in undergraduate education' (Chickering and Gamson, 1999). The responses of Tutors and Tutees reflected the benefits of the system, for both groups (Kieran and O'Neill, 2009). In developing the PATs, the focus was on the Tutees. However, Tutors reported a deepening of their understanding of the subject material (Unit Operations), coupled with improvements in their communication, time-management and group facilitation skills. Positive Tutee-feedback was significant in deciding to retain and extend the PAT system within the UCD curriculum. Positive Tutor-feedback was crucial in deciding to formalise Tutor involvement, specifically, to offer academic credit to Tutors, based on their achievement of professionally-relevant learning outcomes, within the framework of the PATs.

2. MODULE DEVELOPMENT

2.1 Criteria for the Development of the Peer Tutoring Module

UCD operates a modularised system, under which 4-year Engineering programme students select six, 5-credit, elective modules (from a total of 240 credits). Electives may be either 'in-programme' (*i.e.* from within the student's core discipline) or 'non-programme' (*i.e.* from any other discipline offered by the University, pending pre-requisite, time-tabling and capacity restrictions). The Peer Tutoring module was developed as an 'in-programme' elective, aimed at 4th Year Chemical Engineering students. In developing the module, emphasis was placed on designing a module aligned with the outcomes of the Chemical

Engineering degree programme. To meet Level 9 accreditation requirements of Engineers Ireland (2007) (equivalent to NQAI Level 9), for examples, programmes must enable graduates to develop 'a knowledge and understanding of group dynamics and ability to exercise leadership'; additionally, graduates should 'communicate effectively with the engineering community', and 'understand the training needs of others in appropriate engineering techniques'. Timing of the Peer Tutoring module was critical; it must be offered during a semester in which any PAT-supported 3rd Year modules are scheduled and during which 4th Year students enrol in an elective. The module workload must not exceed the 100-120 hour limit, as specified for all 5-credit, semester-long modules. Finally, in developing the module, issues arising from the 2008-09 pilot series of PATs, as identified by Tutors, Tutees and associated staff, were addressed. Tutors highlighted the importance of adequate preparation for PATs and of learning to lead Tutees towards a solution. They also suggested that Tutors might work together in pairs (as applies with PAL (Fleming, 2008)). Based on the success of the pilot scheme, PATs were also extended to another core, 3rd Year module, CHEN30160 (Computational Methods in Chemical & Bioprocess Engineering). Module descriptors for all UCD modules are available online (UCD, 2010).

2.2 The Peer Tutoring Module

Based on the criteria identified above, the Peer Tutoring module was developed. Learning outcomes, learning activities and modes of assessment are summarised in Table 1. The learning outcomes (Table 1(a)) reflect the personal- and discipline-related gains accruing to Tutor involvement in the PATs. As both the Unit Operations and Computational Methods modules are compulsory for 3rd Year Chemical Engineering students, with occasional exceptions, the same students are enrolled in both modules. For PATs in both subjects, it was decided to assign the Tutees to the same group of 5-6 students. Tutors would be assigned to (self-selected) pairs; each Tutor pair would work with a different Tutee group for both subjects. In this way, each Tutee group had increased opportunities to develop as a team, while each Tutor pair was exposed to a total of 10-12 Tutees over the course of the semester. A key challenge was the development of an appropriate strategy for assessing Tutor achievement of learning outcomes (Table 1(b)) in the affective domain. The emphasis was on encouraging, supporting and rewarding full Tutor engagement with the PAT process; it was imperative that the Tutors be professional in their approach to their new teaching role and 50% of the module grade was allocated to preparation for, attendance at & participation in assigned PATs. Tutors were required to critically reflect on the success of their tutoring activities and the development of their skills over the course of the semester, presenting their findings in an end-of-semester reflective report. In preparation for this report, based on established principles of reflection on practice, each Tutor was required to develop an evidence-based portfolio of associated material, consisting of the following elements:

1. **Online Blogs:** To encourage timely and shared reflection on the PATs, Tutors contributed to BlackBoard-based blogs for both Unit Operations and Computational Methods PATs. Each Tutor initially contributed a personal reflection on his/her experience of the PAT; Tutors were then required to read the accumulated reflections and contribute at least one reflective response.
2. **Collective Reviews:** For each PAT, there was a short, structured, Collective Review, facilitated by the Chemical Engineering post-graduate student assigned as a Teaching Assistant to the PATs in that subject. This review was intended to discuss issues raised in the blogs.
3. **Tutee Feedback:** At approximately mid-semester, Tutees were invited to provide feedback on their Tutors. Feedback was collected via in-class survey forms. Results

were confidential to each Tutor and to the Module Coordinators. Tutees were notified that their feedback could not affect the Tutor's grade in the Peer Tutoring module.

4. **Tutor-Partner Feedback:** During a single PAT in both subjects, each Tutor evaluated his/her partner; prior to the evaluations, each pair of Tutors identified aspects of personal performance on which they would particularly welcome feedback. The results were confidential to the Tutor pair but each Tutor was required to reflect on his/her evaluations in the end-of-semester report.

Table 1 Summary of module information for 'Peer-Assisted Tutoring in Chemical Engineering': (a) Learning Outcomes, (b) Modes of Learning & Associated Workload, (c) Modes of Assessment.

(a) Learning Outcomes

On successful completion of the Peer Tutoring module, students should be able to:

1. Facilitate productive team work, in engineering contexts;
2. Effectively communicate, and encourage student communication of engineering concepts;
3. More fully appreciate engineering concepts, through communicating them to others;
4. Critically appraise personal and team performance.

(b) Modes of Learning & Associated Workload

Activity	*Hours*	*Details*
Tutor Training & Module Review	6	2 x 2-hour tutor training workshops during Weeks 1-2 1 x 2 hour Training & Review session during Week 6
Discipline-Specific Training & Review of previous PATs	13	1-hour PAT review/preparation sessions; guided preparation for and review of PATs, scheduled approx weekly throughout semester.
PATs	8	8 x 1-hour Unit Operations PATs
	16	8 x 2-hour Computational Methods PATs
Specified Learning Activities	8	on-line reporting on each PAT (approx 0.5 hour/PAT)
Autonomous Student Learning	65	personal preparation for each PAT, plus report preparation
Estimate Total Tutor Workload	**116**	

(c) Modes of Assessment

Assessment	*Details*	*% of module grade*
Continuous assessment	Preparation for, attendance at & participation in assigned PATs	50
	Short, online reporting on and appraisal of PATs	30
Assignment	1500-2000 word reflective report on Tutor experiences of PATs	20
Total		**100**

The module necessarily involves the application of a diverse range of pedagogical principles. Tutors were introduced to selected relevant topics during the training sessions; key works in the refereed literature were identified. Students were required to research this literature in reflecting on one or more aspects of their development as Tutors. Together, the above activities accounted for 50% of the module grade. Students were encouraged to use Hampton's (2007) guide to interpret and develop outcomes in their reflective writing (i.e. 'What have I learned from this?', 'What does this mean for my future teaching?')

2.4 Module Evaluation

Evaluation processes were strategically embedded in the module. While each PAT was supervised by a Module Coordinator and/or Teaching Assistant, the blogs allowed for timely identification of issues of concern to the Tutors, or to the Tutees (e.g. optimal Tutor-Tutee seating arrangements in the Unit Operations PATs; encouraging participation by quieter Tutees). Regular Collective Reviews allowed for group discussion of these and subject-specific problems. Feedback was formally solicited from Tutors and Tutees, via in-class surveys distributed towards the end of the semester. Questions on the Tutor Survey, relating to Tutor experiences of the Peer Tutoring module, are presented in Table 2. (Questions relating to the Unit Operations and Computational Methods PATs have been excluded; likewise, Tutee feedback is not considered here.) Data from the Tutor Surveys, administered during the penultimate week of the semester, provided a basis for an informal, Coordinator-moderated review of the module with the Tutors, at the end of the semester. This multi-faceted approach to review, although time-consuming, ensured that issues arising could be speedily addressed and difficulties resolved; equally importantly, it ensured that Tutors and Tutees had a real sense of involvement in and commitment to the PATs.

3. IMPLEMENTATION & EVALUATION

3.1 Tutor Recruitment & Enrolment

The Peer Tutoring module was advertised to incoming 4th Year students during Summer 2009. Enrolment was limited to students who had already taken and achieved at least a C-grade in both the Unit Operations and Computational Methods modules. Students applying for admission were invited to attend a short interview with the Module Coordinators. Ultimately, all 12 applicants (6 male, 6 female) were accepted. Students were notified of acceptance in late October. The module commenced in January 2010. (Survey responses, expressed (below) in percentages, refer to the necessarily small population of 12 Tutors.).

3.2 Tutor Training

Tutor training was based on that developed for the pilot PATs (Kieran and O'Neill, 2009). It was delivered with the support of two Teaching Assistants (one assigned to each set of PATs). There was considerable emphasis on Tutor assessment, with a view to evaluating achievement of learning outcomes; the concept of reflective writing was new to all Tutors; a 1-hour session was devoted to relevant pedagogical principles. Formal 'Preparation Sessions' were scheduled for each PAT, allowing Tutors to refamiliarise themselves with the subject material and to identify concepts with which Tutees might struggle.

3.3 Tutor Experiences of the Peer Tutoring Module – Survey Results

3.3.1 Achievement of Module Learning Outcomes

Overall, Tutor feedback on the Peer Tutoring module was extremely positive and reflected a very high degree of congruence between the expectations and perceptions of both Tutors and the Module Coordinators. All Tutors were 'very much'/'fully' aware of the module learning outcomes; all believed that they 'very much'/'fully' achieved those learning outcomes and that the methods of assessment 'very much'/'fully' supported them in this undertaking. With regard to development of specific skills, Tutors expressed most satisfaction with their improvements in the areas of 'facilitating teamwork' (100%: 'very much'), their own 'understanding of engineering concepts' (100%: 'very much'); 10 out of 12 Tutors (83.3%) believed they had 'very much' improved their skills in the areas of 'communicating engineering concepts', 'encouraging communication of engineering concepts' and 'understanding and supporting the learning process in others'. The areas in which Tutors registered the lowest levels of improvement were critical appraisal of 'personal performance' (66.7%: 'very much') and 'team performance' (50%: 'very much'). Only one-third of Tutors found the training 'very much' effective; the remainder evaluated it as 'somewhat' effective in supporting the achievement of learning outcomes. Tutors indicated that the training sessions could be shortened (‘a single session would probably have sufficed’); no topics were identified as irrelevant, no omissions were identified (‘Good introduction to the module’). Tutor opinions on the effectiveness of the modes of assessment were more divided. 25% of Tutors found the blogs ‘not at all’ useful, while the remainder evaluated them as either ‘somewhat useful’ (58.3%; ‘They were good at the start but as time went on they became less useful & repetitive.’) or ‘very much’ (16.7%). However, in-class discussion revealed that, in working on the end-of-semester reflective report, the blogs provided an invaluable record of PAT experiences; Tutors agreed that the requirement to make blog entries was very effective in ensuring timely and sequential review of their efforts. Both the surveys and in-class discussion revealed some overlap between the blogs and the Collective Reviews. Although 2 Tutors found the Reviews ‘very’ useful (‘It was great to talk through problems and realise other groups had similar problems and then discuss solutions.’), the remainder evaluated them as either ‘somewhat’ useful (58.3%; ‘Either these or the blogs; both are not necessary as we just tended to repeat things in the review sessions.’) or ‘not at all’ useful (25%; ‘We Tutors discussed the PATs informally, so this formal method was repetitive’). The Tutors were more enthusiastic about the mechanisms for feedback from Tutees (all ranked this element as either ‘very much’ (58.3%) or ‘somewhat’ (41.7%) useful (‘It gave a good insight into how the Tutees were feeling & where I needed to improve.’). With regard to the Tutor Partner Feedback, all but one of the Tutors rated this as ‘somewhat’/’very much’ useful.

3.3.2 Tutor Motivation for Enrolling in the Module

Since the introduction of the Horizons system in UCD, which allows students to choose a limited number of elective modules, there has been concern about the bases on which students will choose these modules. However, a campus-wide study of students enrolled in non-programme electives (Hennessy et al., 2010) revealed that, although a substantial minority of students consciously seek an ‘easy option’, the majority are most highly motivated by an interest in the subject area. Encouragingly, the students who enrolled in the Peer Tutoring module were primarily motivated by the professional relevance of the module (91.7% ‘very much’), the opportunity to improve their communication skills (83.3%) and the opportunity to improve their understanding of the subject material (66.67%).

3.3.3 Overall Evaluation of Tutor Experiences of the Module

Just over half of the Tutors evaluated their experience of the module as ‘very useful’ (58%; ‘assisting student development was very satisfying’); the remainder judged it to be ‘useful’. For the Tutors, the most frequently cited ‘best aspects’ of the module were the satisfaction associated with supporting the Tutees in their learning, interacting with the Tutees, personal development of associated skills (‘growing in confidence as a leader’, developing my communication & team work skills’); increased understanding of the relevant subject material (‘I got to know the subject matter in great detail’). In conclusion, 10 of the 12 Tutors (83.3%) confirmed that ‘if they’d known in September what you known now’, they would have enrolled for the module; the same number confirmed that they would recommend the module to the 3rd Year students. In both cases, the dissenting students answered ‘maybe’; no Tutor responded negatively to either question.

3.4 Tutor Experiences of the Peer Tutoring Module – The Time Factor

Time-related issues were explicitly addressed in only one question in the Tutor Survey (Table 2, Question 6). However, workload was identified by 9 Tutors as the ‘worst aspect’ of the module. Specifically, Tutors felt their time commitment for this module was significantly greater than for other elective modules pursued by their classmates. However, they admitted that this module contributed to their personal, professional and academic development to a greater extent than so-called 'easy options'. They unanimously agreed that they did not devote more time to it than anticipated (Table 1(b)); in fact, they admitted spending less than 116 hours on the module. But their involvement in the module was very well-defined and they felt a greater onus to attend each scheduled element than every lecture in a 'normal' module.

Table 2 Survey questions addressed to Tutors, relating to their experiences of the Peer Tutoring Module. Where appropriate, 4-level Likert-scale or yes/no response options were employed. An asterisk indicates that Tutors were invited to comment on their responses.

Achievement of Module Learning Outcomes

1. To what extent were you aware of the learning outcomes for this module?

2. To what extent do you feel you achieved the learning outcomes?

3. Overall, to what extent do you feel the module assessment supported your learning?

4. To what extent do you believe your skills in each of the following areas improved, as a result of your involvement in CHEN40430?
- (a) facilitating productive team work, in engineering contexts?
- (b) effectively communicating engineering concepts?
- (c) effectively encouraging student communication of engineering concepts?
- (d) your understanding of engineering concepts, through communicating them to others?
- (e) understanding and supporting the learning process in others?
- (f) critically appraising student/team performance?
- (g) critically appraising personal performance?

5. How useful did you find the following in supporting your achievement of the learning outcomes?
- (a) ‘General’ Tutor-Training Sessions?*
- (b) UO Prep Sessions?*
- (c) CM Prep Sessions?*
- (d) Online Blogs?*
- (e) Collective Review Sessions?*
- (f) Tutee Feedback?*
- (g) Tutor-Partner Observation?*

6. *Excluding* the scheduled preparation sessions, on average, how many hours did you spend preparing for each (a) Unit Operations O PAT and (b) Computational Methods PAT?

Tutor Motivation in Enrolling in the Module

7. How important were each of the following factors to you in deciding to enrol in CHEN40430?
- (a) professional relevance?
- (b) improving communication skills?
- (c) improving your understanding of the topics?
- (d) mode(s) of assessment?
- (e) interest in teaching?
- (f) other? (*please specify*)

Overall Evaluation of Tutor Experiences of the Module

8. Overall, how would you evaluate your experience as a Tutor?*

9. With what aspects of your work as a Tutor were you most satisfied?

10. What aspects of your work as a Tutor most require improvement?

11. If you knew last September what you know now, would you still enrol in CHEN40430?*

12. Would you recommend this module to 3rd Year students for next year?*

13. What were the best aspects of CHEN40430?

14. What were the worst aspects of CHEN40430?

15. What changes to CHEN40430 would you recommend for next year?

4. CONCLUSIONS & RECOMMENDATIONS

The Peer Tutoring module is an example of how the development of transferable skills, in a discipline-specific context, may be incorporated into an Engineering curriculum. Although specifically applied within a professionally-accredited Chemical Engineering programme, there is obvious potential for implementation within other Engineering disciplines. The current paper reports on the initial offering of the module, involving only a relatively small number of Tutors (12). Additionally, only Tutor experiences have been considered here; a longitudinal study of the impact of the module on the Tutees involved is also required. For the immediate future, Tutor feedback will be used to modify the module. Although, dialogue with others is a key aspect of reflecting on teaching/tutoring practice (Brockbank and McGill, 2000), evidence from the current study suggested that the extent of both blogs and Collective Review sessions could be reduced, with associated reductions in Tutor workload.

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ACKNOWLEDGEMENTS

The authors gratefully acknowledge the support of the SIF-funded UCD Fellowships in Teaching & Learning and of a NAIRTL Teaching Award, in the development, implementation and evaluation of the PATs. They also thank the UCD undergraduate and postgraduate students in Chemical Engineering who have participated in the PATs over the past 2 academic years.

PLACING POSTGRADUATE RESEARCH STUDENTS AT THE HEART OF KNOWLEDGE EXCHANGE: BENEFITS FOR ACADEMIA AND INDUSTRY

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Abstract

This paper describes the process of establishing an industry-driven Postgraduate level research degree programme that embedded the values of knowledge exchange (KE), particularly business support, whilst maintaining academic rigour. This aim was achieved by placing research students at the heart of KE as a discipline whilst undertaking research that would be of direct, tangible relevance to industry, ensuring that research activity was user-driven. The activity was focussed geographically in England's North West (NW) Region allowing it to dovetail with the priorities of regional economic strategies and growth initiatives, and particularly, those of a technical nature delivered through Lancaster University. These programmes work primarily with Small to Medium Sized Enterprises (SMEs) and so the development of the research degree programme had to accommodate these requirements, unlike conventional (taught) industry-based degrees that can work largely with multi-nationals and other corporate organisations.

The paper further outlines the innovative MSc Engineering (by Research) programme that has been piloted by Lancaster Product Development Unit, the team that co-ordinates the KE activity for the Engineering Department at Lancaster University. It demonstrates how industry focussed problems have been addressed to varying extents by the utilisation of several research-focussed Masters-level degree students. It further highlights how economies, educators and students can all benefit from Postgraduate degrees delivered from within a KE environment. The paper finally goes on to conclude that whilst added resources are required over traditional and more established degree schemes, that very effective outcomes can be obtained, capitalising on the tailored nature of the processes and methods of delivery.

Keywords: knowledge transfer, knowledge exchange, SMEs, PGR.

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1. INTRODUCTION AND BACKGROUND

The term knowledge exchange (KE) has relatively recently seen an increase in Higher Education (HE) as a means of linking industry with academia and in so doing, fostering mutually beneficial relationships for economies, educators and students. The notion of KE is not a new one and basic applied research from universities can be traced back to the early 19th Century (Atkinson and Blampied, 2008), where European universities began to shift from merely the dissemination of knowledge to also include the production of that knowledge. Of note too in the early stages of KE is the US Morrill Act of 1862 in which land was sold to generate revenue, providing investment for state-level education institutes. A responsibility of these new places of scientific and technological know-how was the propagation of knowledge into mainly agricultural communities and so seeking to boost the economic activity by way of transferring knowledge (Collier, 2002). Modern day KE principles between universities and the wider community have seen relatively little change, yet the prominence and priority of such activity has risen considerably.

KE (interchangeable with the term knowledge transfer) can be defined as "To seek to accelerate the two-way flow of people and ideas between the research environment and wider economy, and thereby contribute to national prosperity, the quality of life of UK citizens, and cultural enrichment of our society. Knowledge Transfer encompasses the systems and processes by which knowledge, expertise and skilled people transfer between the research environment (universities, centres and institutes) and its user communities in industry, commerce, public and service sectors." STFC (2009). With potentially wide-ranging benefits for all stakeholders, KE is now becoming a more established part of universities and embedding itself in the culture of the HE sector. There are many ways in which KE occurs, which can be broken down to offer some structure to the expanding field. The following categories can be referred to as channels of interaction Polt *et al* (2001):

- "Collaborative research;
- Contract research and technology-related consulting;
- Personnel mobility between firms and public science institutions;
- Co-operation in the education of graduate students;
- Vocational training for employees;
- Use of intellectual property rights (IPR) by public scientific organisations;
- Start-ups of technology-oriented enterprises by researchers from public scientific organisations;
- Informal contacts and personal networks."

2. KNOWLEDGE EXCHANGE AND THE SME

In an extension to the category 'contract research and technology-related consulting' a significant area of activity has developed specifically focussed around business support for Small to Medium-sized Enterprises (SMEs). Such a category has the potential to include elements of all of those listed above providing not only a diverse mixture of different aspects of KE, but also a thorough, deeper level of collaboration between organisations. Business support, as distinct from other categories of KE may be defined as: a state-funded project based on a formal contract where knowledge is exchanged for the benefit of all parties, and whereby a meaningful level of intervention is provided so that commercial advantage can be gained. In this context it would be usual for two organisations to be directly involved: an HEI and an SME. It would be expected that intervention would normally result in the SME demonstrating an increase in competitiveness, and therefore leading to commercial gains. Whilst similar aims exist for collaborative ventures with larger organisations (Santaro and Gopalakrishman, 2000), including the institutionalisation of KE, the focus of this paper is with the link between universities and SMEs.

The framework for business support for SMEs can be very different to the more traditional methods outlined above in the way that the two organisations are introduced, the wide role taken on by the university and the support structures in place for such activity. Indeed, it has been reported that there are differences in the way university-industry engagement is investigated: perspective (industry, university, government), structure (formal, informal), level of analysis (market, organisation, individual) and effect (economic, academic, scientific capacity, institutional, cultural, management) (Boardman and Ponomariov, 2009). It would be naive to assume that each of these areas could be investigated in-depth within a single KE study and so the focus here will be on the effects of KE, from different perspectives; including individuals, organisations and commercial entities. Paisey and Paisey (In Press) cite several benefits from utilising students in the knowledge transfer process, both for academia and industry. These are plentiful and some of the most important for the HEI include that it was found to increase student motivation as they see value in their work; informing students of future career paths; and one very commonly cited benefit is the use of placements as a vehicle in effectively developing skills. On the side of the employer, it included the creation of 'learning cultures'; developing commonly-sought attitudes within graduates; wealth creation; and the encouragement to critically evaluate or question underlying assumptions concerning an organisations method of operating (Paisey and Paisey, In Press).

3. KNOWLEDGE EXCHANGE AND THE STUDENT

Traditionally, engineering students within HE experience industry engagement via one of two models. The first is a short-term placement scheme, typically lasting up to 100 hours of project time in which the student would work on a company-focussed problem or opportunity, normally not critical to that company but that could bring benefits. Secondly, longer schemes such as Knowledge Transfer Partnerships (KTPs), Collaborative Awards in Science and Engineering (CASE) studentships and a year-in-industry offer the opportunity for a more in-depth piece of research and development. Such schemes can last between 1 and 4 years and for KTPs and CASE, the student would normally be registered for a higher degree; a Masters and/or a PhD respectively.

There are significant benefits to both of these models: in the case of shorter-term placements, the student has the opportunity to work with industry allowing them to apply theory to practise without the commitment or responsibility of something more long lasting. It allows them to see how they may be suited to a particular industry or field whilst developing softer skills around time management, confidence, communication and project management. The company benefits in that there is an additional low-cost (if any) resource that brings a fresh approach and potentially innovative ideas. The company are able to consider the student for potential recruitment into a paid-position on completion of the course or in vacation periods. In the case of longer-term collaborative ventures, key benefits for the student include working on a project that has potentially a large impact on the host company, significant development of research and analytical skills as well as exposure to an industry, enabling networking and further opportunities. With such projects, it is clearer to see the benefits to HEIs, such as fostering regional (or national) relationships, the publication of papers and the application of research. The latter point becomes more pertinent with the introduction of the Research Excellence Framework (HEFCE, 2010) which places a greater emphasis on impact factor; a demonstrable attraction for academic staff.

4. KNOWLEDGE EXCHANGE AND THE UNIVERSITY

These advantages help to reinforce the utilisation of student resource for bridging the link between academia and industry. Business support, as highlighted earlier is becoming a significant part of HEI-engagement for some institutions and Lancaster University has been leading in this area, particularly developing regional programmes dedicated to SMEs. Between 2002 and 2008, Lancaster University worked with over 2000 regional businesses, social enterprises and community organisations through a range of economic regeneration activities. Some of this activity was evaluated as part of a comprehensive impact investigation which found that Lancaster University, via the utilisation of publicly funded resources, contributes towards the achievement of economic objectives set by Government policy, amongst them, to help build capability within a business to improve its growth, and to create new jobs (Flores-Romero *et al*, 2008). These outputs are delivered by eight KE teams on campus whose remit includes the transferring of knowledge for the overall benefit of the stakeholders involved.

One team, based within the Engineering Department is Lancaster Product Development Unit (LPDU), which since its inception in 2002 has worked with over 600 companies, created 300 new jobs, generated £30M of new sales and co-ordinated the placement of 200 students with industry. Over £5M of funding has been delivered and currently (2009 – 2012), an anticipated £2.9M will further be delivered. The principal source of funding for this activity continues to come from the European Regional Development Fund (ERDF), supported by the Northwest Regional Development Agency (NWDA) and the Higher Education Council Funding for England (HEFCE) through its Higher Education Innovation Fund (HEIF), currently in its fourth phase (2009-11). Much of the money secured from European Union sources, such as ERDF is required to be matched by the university, by way of time input which is secured from members of staff. The KE team is a vibrant node, acting as a conduit between industry (largely SMEs) and the knowledge base, through the academic Department in which it resides.

5. DEVELOPING AN INDUSTRY-RESPONSIVE POSTGRADUATE RESEARCH PROGRAMME

In developing links with industry, the LPDU team noted the extensive benefits of KE for not only the many companies it worked with, but also in recognising that the process has reflective positive impacts for the University. This, combined with the advantages outlined earlier of engaging students with KE led to the development of an MSc Engineering (by Research) programme that complimented the aims of LPDU whilst also striving to achieve wider institutional objectives related to research outputs. The course is a research-led programme, meaning that there is no formal taught element to it, such as would be found with traditional Masters Courses; although the acquisition of learning credits is a requirement. Learning credits are obtained through participatory means such as at workshops, conferences or internal courses, and 20 credits must be achieved which is equivalent to approximately 10 days of research training/learning or direct dissemination of research (such as presenting at conferences/seminars etc..). The course can be completed either as a full-time (12 month) or part-time (24 month) programme, with a total of 1800 learning hours.

The educational aims of the programme in respect of subject-specific knowledge, understanding and skills, are:

- To develop a systematic understanding of knowledge, and a critical awareness of current problems and/or new insights, much of which is at, or informed by, the forefront of their academic discipline;
- To develop knowledge and understanding of fundamental scientific issues, underpinning a specific area of engineering;
- To introduce students to methods relevant to research in their specific area of engineering and related disciplines;
- To enable students to demonstrate originality in the application of knowledge, together with a practical understanding of how established techniques of research and enquiry are used to create and interpret knowledge in the discipline;
- To develop conceptual understanding that enables the student:
    - To evaluate critically current research and advanced scholarship in the discipline;
    - To evaluate methodologies and develop critiques of them and, where appropriate, to propose new hypotheses.

The intended learning outcomes for the subject-specific knowledge, understanding and skills, following successful completion of the course are:

- Demonstrate understanding of both theoretical and practical aspects as applied to both current and future developments in engineering;
- Investigate and solve a significant practical or theoretical problem using their engineering-related practical abilities;
- Demonstrate appropriate choices of research method and apply them to their problems, showing awareness of relevant ethical, social, professional and legal factors;
- Produce a fully referenced written academic report (30,000 word thesis) of their project activities appropriate to the field of engineering.

Subject areas can be a difficult aspect to contend with in the context of a degree that is offered at a Masters-level, yet has a research focus because of its potential for scope. There has to be a clear synergy with Departmental activity as well as availability of staff members willing to offer supervision and provide necessary resources (both in terms of their own knowledge and access to technical equipment and facilities). A major priority for offering a course in the KE environment is that it has a considerable amount of real-world focus and that the stimulus for the research comes from the opportunities and challenges presented by industry. Funding streams such as ERDF have a large role to play in addressing these regional economic challenges and so it becomes clear how the resources of an MSc (by Research) programme can be used in KE to help achieve mutual benefits. The robustness of the rationale in using a PGR programme in this manner is also given a degree of verification through the business plans and approval processes that are required for being granted projects, such as those funded by ERDF and administered by regional secretariats.

To ensure that industry focus is not merely an impetus at the beginning that may have a tendency to ebb once a student is enrolled onto the scheme, the MSc (by Research) makes provision for external input alongside the two internal supervisors. Students meet their first supervisor typically once a week for an hour to check progress and agree actions for the following meeting, which helps to ensure academic rigour. In addition to this, the LPDU seeks to appoint an external advisor to each student that would be utilised in a more flexible manner, than supervisors. The appointment of an external advisor may be done through existing formal or informal relationships or through the appointment of somebody remunerated for providing that service. In either case, a significant level of expertise in the subject area is key, and where mutually beneficial outputs can be identified, this is clearly a much more desirable option.

KE funding programmes and in particular those funded by the EU, such as ERDF come with regulations and eligibility criteria which introduces an alignment issue if one seeks to combine such activity with research. In the first issue, eligible companies under the programmes delivered by LPDU must be a SME under the EU definition and must support the priorities of the programme. Most industry sectors can be worked with but there are notable exclusions by way of regulation such as retail and those companies that serve only local markets. Other exclusions exist by the very nature of the business sector and given the expertise of an Engineering Department, a professional services consultancy firm would seek more effective KE engagement elsewhere. Beyond working across a variety of diverse sectors, the Northwest has six key priority sectors: Bio-medical; Energy and Environmental Technologies; Advanced Engineering and Materials; Food and Drink; Digital and Creative; and Business and Professional Services. These criteria and funding regulations help to guide the research being conducted, acting in a funnel-like fashion.

Since 2007, there have been nine students graduate, or due to graduate this year from the MSc Engineering (by Research) programme within the LPDU team. Attributable to these students, there have been 35 engagements with industry where all but two were with SMEs. Engagement with industry is described as where the student completed work which subsequently had an impact on the companies working practices in one or more specific area(s), which would not have normally occurred if that company had continued ‘business as usual’. It is also used to include where a company informed the research of the student whereby a practical application was experienced by that student that would not have normally been achieved through traditional learning methods. In addition to these 35 engagements, a further 47 more superficial interactions took place, which essentially involved the completion of questionnaires by industry to inform the student’s research. In total, therefore 82 individual interactions or engagements have occurred between the MSc (by Research) programme and industry. Due to the specificity of the industry sectors, the funding regulations and the geographical constraints, some repetition occurred, which was not prevalent (five occurrences) and was mainly a consequence of the selection of external advisors.

6. BENEFITS SURROUNDING THE PLACING OF PGR STUDENTS AT THE HEART OF KNOWLEDGE EXCHANGE

A major advantage in engaging with SMEs is the flexibility that this affords, both in terms of the structure of the intervention as well as access to information. Larger organisations that have rigid hierarchies with clearly segregated departments are likely to find access to information more time-consuming as requests are made to different parts of the company. For example, central services, such as those processing invoices that may be required to determine the amount of energy a company uses, may be reluctant to comply with non-standard requests. Smaller firms where the managing director (MD) has access to data on all aspects of his/her firms operations are likely to be able to source required information, providing their files are well kept.

As an extension to the point of adaptability, working with SMEs has the potential to evoke considerable change to the way businesses operate if they believe the change offers real benefits. This is not to assume that small businesses can change the world overnight but by working directly with the senior management, decisions on how business is conducted can be made and implemented very quickly whereas in larger corporations, this would take time, particularly if working below board or director level. The notion of working with the decision makers in small firms to enact change or respond to opportunities becomes more significant when networks or clusters are targeted. This may be sector-specific, supply-chain-linked or related to the geographical make-up of a region or locale. For example, the Cumbria Green Business Forum is an organisation dedicated to promoting environmental best practice for the benefit of its members, helping to secure the longer-term economic priorities of the county of Cumbria. LPDU engaged with the group to work with individual companies in developing carbon footprint methodologies. In so doing, the forum was able to offer services to its clients, the companies were provided with detailed carbon footprints including extensive information and recommendations, and the PGR students were able to work with businesses from the region with an interest in climate change related issues.

The drawbacks of working with SMEs, whilst noteworthy, should not preclude partnership building or collaborative ventures between HEIs and industry. The authors merely seek to identify some of the recurring barriers experienced when working with Northwest SMEs and view the advantages in KE as far outweighing any drawbacks. The flexible nature of small businesses identified earlier can simultaneously be a weakness as the day-to-day challenges of running a company can understandably take precedence over KE activity. The resultant effect can mean a project stalling because of information not being forthcoming from the company. Defining clear outputs as well as identifying a sole company contact can help to address these points (and champion the KE activity from the industry side), which should be done as early on in the KE process as possible. Personnel changes at companies part-way through intervention projects have also caused problems; management restructuring or changing roles mean that new people may not necessarily view any activity with HEIs as being worthy of action or as high a priority as predecessors. Such changes are impossible to predict and so working with companies where a longer lasting relationship exists does help to safeguard against such eventualities, if only to a certain degree.

Ultimately, an organisation whose job it is to make money is unlikely to enter into a partnership with an HEI unless there are tangible commercial outputs. Managing the expectations at this point can be difficult, as SMEs from our experience tend to want data that show them as leading against their competitors. Providing this sort of detail is often at odds with the research being conducted, as this tends to focus on the host company, rather than attempting to draw industry-wide comparisons. In addition, written material that is fit for purpose as a research output (at a Conference for example) may well be inappropriate for an MD to use in attempting to make some business change, whereas, given the publishing landscape of a research-led university and the pressures on academics to produce papers, can be at stark odds with what would be acceptable to an SME as something worthwhile to their business. The conflicts of what is acceptable to different audiences results in the regurgitation of information, and whilst this is not directly reproducing it, there is a time resource required for addressing such differences.

An intention of this discussion was to consider some of the effects of KE from different perspectives, such as those of student, institution, department and SME as well as any wider impacts. There are for the student, some important transferable skills that are developed through an industry-focussed research degree over conventional HE degree schemes, the first and most obvious being the exposure to companies and the high value placed on the application of research. This has the advantage of fully equipping the individual in a way that is unique, allowing them to hone into a very specific subject area. Within LPDU, as outlined earlier, these have been aligned to the business support initiatives, and include two main areas: responses to climate change and additive manufacturing. With the former, students have researched the development of carbon footprint methodologies for SMEs, whilst in the latter examples include developing user-friendly design tools for additive manufacturing technologies. Both examples demonstrate how students can conduct research with a sustained feedback loop from companies engaged in the respective field.

There are some advantages in operating this programme from the viewpoint of the academic Department. Firstly, its PGR count rises, meaning a greater measure on making returns institutionally and reporting to external bodies, such as research councils. There is a value-for-money argument to be made in that the resources for a dedicated student in terms of paying the fees (approximately £3,500 per annum) plus a Maintenance Living Allowance (£8,500) for the same period to help cover living expenses. In comparison to this, a full time member of staff employed to work on a one-year project would cost considerably more. The generation of at least one research paper is also something that is encouraged: ideally, this would be two, gaining a Conference and a Journal paper where timescales permit. This gives credence to the students work when it is required to be defended at viva voce examination and raises the exposure of the Department, contributing to the aims of the institution as being research-led.

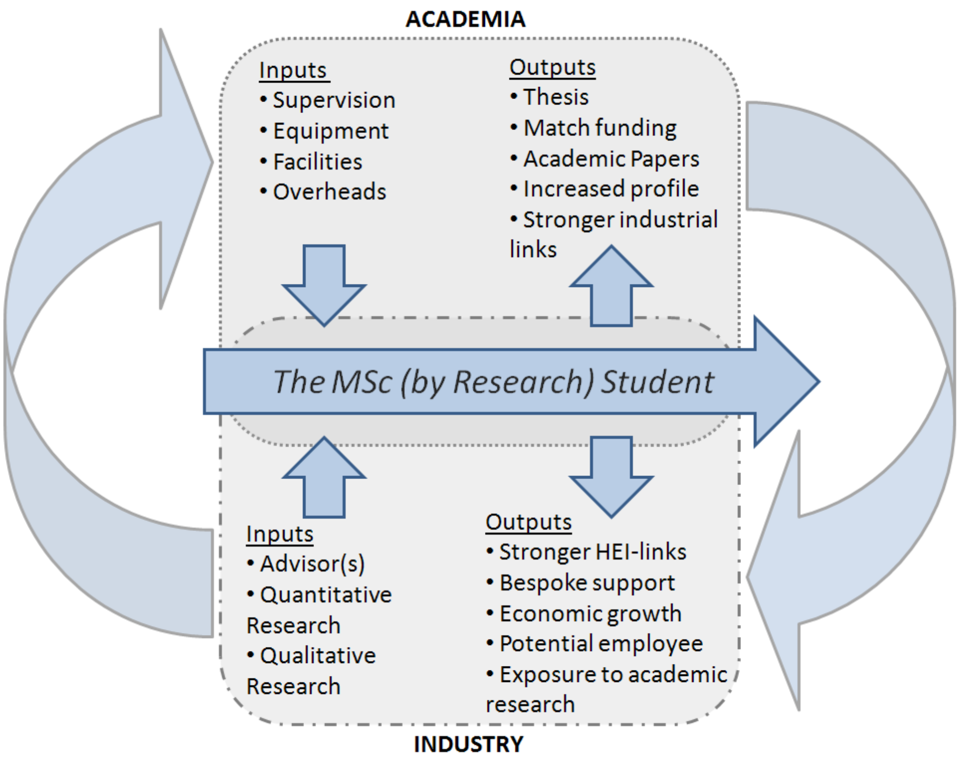

Figure 1: model to represent how the MSc (by Research) programme interacts with academia and industry and provides a stimulus for effective KE

In reference to Figure 1, the interactions are highlighted by considering the inputs and outputs of the student as he or she progresses through their studies, both in terms of time and also knowledge. Whilst the diagram shows inputs earlier, these – particularly on the academic side – continue throughout, up until the very day the degree is complete, which would normally be the final submission following viva voce examination. The model prepares a student so that upon completion they have the necessary knowledge and skills to begin a career in the field, and in some circumstances, this has been seen as a good model to take a year out, leave one industry and enter into another; this has been achieved to good effect. Other inputs and outputs are likely to occur dependent upon the nature of the research; the model seeks to highlight the interactions and main pathways therein.

The structure of these projects means that funding drawn down from the European Union is required to be matched by time resources from the institution. Through this method, a rate can be applied to the student based on their Maintenance Living Allowance and provided that the work they are doing is eligible under the regulations, then they are able to be matched against EU grant. This has benefits as it reduces the amount of match-income required by other means such as traditional academic time, which is often in demand for the more mainstream activities of teaching, research and administration.

The impacts that are felt from individual companies are much more difficult to quantify than those experienced by the academic Department, not least because it depends not only on what a company receives but then how that is interpreted and more importantly, what is done with it. Should the work undertaken provide them with information that discourages them in promoting it or furthering it, then the project is likely to come to an abrupt halt. If however, the work assists in promoting one of their business interests, perhaps to support claims or help in evoking positive change, then the research undertaken could have significant impacts for that one company. In addition, the objectivity and independence enjoyed by a university study can be a large factor in attracting a company to collaborate. Such impartiality can help endorse a product or service, but scientific evidence must remain paramount, which is perhaps why some of the most successful engagements are the ones not necessarily in the limelight.

7. CONCLUSION

The impacts of the MSc Engineering (by Research) Programme at Lancaster University's Engineering Department, have been found to be positive to all stakeholders involved in the process, not least by providing meaningful results to targeted companies, which were inspired by the challenges and opportunities provided by industry as a whole. Sectoral application has been wide yet focussed in by the priorities of regional economic strategies and growth initiatives delivered by LPDU. Being of a technical nature has allowed them to be research-compliant and supported by the Department, the work has produced meaningful, tangible outputs for student, Department and SME. Embedding PGR students at the heart of KE has been shown to have tangible benefits for all parties and whilst not without some inevitable difficulties, can be made to work successfully.

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THE ROLE OF THE INTERNET IN ACADEMIC HONESTY: A COMPARISON OF ENGINEERING AND BUSINESS STUDENTS

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Abstract: This paper explores students' attitudes towards and engagement in plagiarism arising from the use of printed and intertnet sources, comparing students from engineering and business courses and taking into account the gender variable. A questionnaire was administered to a sample of 708 undergraduate university students at an Irish institution. Concurring with much of the existing literature; analysis of the data show that females report less engagement in plagiarism and hold stronger ethical views about it than males. The discipline variable was not found to be associated with students' ethical views regarding plagiarist behaviours, but business students declared to engage in plagiarism to a lesser extent than engineering students particularly when it involved the internet. Findings also suggest that engineering students are more likely than business students to use the internet as a source for un-referenced text. Overall students think that using the internet to plagiarise is less wrong than copying from other sources. The results are discussed in the context of existing literature.

Keywords: plagiarism, academic honesty, engineering education, internet sources, gender differences.

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1. INTRODUCTION

Although academic dishonesty is not a new phenomenon, it has been brought to the forefront in recent decades, especially in the light of the ease of access to information that the Internet has made possible. Much of the literature on academic honesty has been built upon students' own reports of their perceptions and behaviour, mainly in relation to perceptions of peer behaviour (Franklyn-Stokes and Newstead, 1995; McCabe and Trevino, 1997; McCabe et al., 2001, 2002; Vandehey, Diekhoff, and LaBeff, 2007; Whitley, 1998; Williams and Janosik, 2007); ethical views (Chaky and Diekhoff, 2002; Franklyn-Stokes and Newstead, 1995; McCabe and Trevino, 1993; McCabe et al., 2002; Scanlon and Neumann, 2002); and gender (Elzubeir and Rizk, 2003; Franklyn-Stokes and Newstead, 1995; Genereux and McLeod, 1995; Hendershott et al., 1999; Koul et al., 2009; Selwyn, 2008a, 2008b; Tibbetts, 1997, 1999; Underwood and Szabo, 2003; Whitley, 2001; Whitley et al., 1999). However few studies have explored students' views according to discipline and almost none have approached differences across different disciplines. This study addresses this gap in the existing literature by comparing reported engagement in plagiarism and ethical views about plagiarism in a sample of business and engineering students, taking into account gender and internet use. The aim of the study is to understand the impact of discipline and gender on attitudes towards and engagement in plagiarism. Additionally, the impact of the internet on plagiarism is examined. To this end the following three questions are posed:

Question 1: Are there differences between students' engagement in and ethical views of plagiarism based on discipline?
Question 2: Are there differences between students' engagement in and ethical views of plagiarism based on gender?
Question 3: Are there differences between students' engagement in and ethical views of internet based and non-internet based plagiarism?

2. METHOD

2.1 Data Collection

A structured questionnaire was administered to a convenience sample of business and engineering, students at the University of Limerick using independent researchers[1]. The students were all in either their first year or second year of study and were all subject to the same policies and procedures with regard to plagiarism. The questionnaires were administered in class settings, thus reducing the self-selection bias that electronic questionnaires usually introduce. The anonymity and confidentiality of the responses was guaranteed in writing at the beginning of the questionnaire.

2.2 Research Instrument

The questionnaire was an adaptation of Scanlon and Neumann's (2002) research measures exploring ethical attitudes towards plagiarism and self-reported engagement in plagiarism. Students were presented with the six scenarios, the first three based on non-internet plagiarism and second three based on internet enabled plagiarism:

1. Copying text and inserting it in a paper without citation
2. Copying an entire paper without citation
3. Asking someone for (or buying) a paper and submitting it as your own
4. Using the Internet to copy text and insert it in your paper without citation
5. Using the Internet to copy an entire paper without citation and submitting it as your own
6. Using the Internet to ask for (or purchasing) a paper and submitting it as your own.

Students were asked to indicate how often they engaged in the above activities and also whether they considered it wrong to engage in these activities. Responses were recorded using a five point Likert-type scale ranging from 1 (*never*) to 5 (*very frequently*) and from 1 (*strongly agree*) to 5 (*strongly disagree*) as appropriate. Newstead et al. (1996) noted the paradox of requiring survey participants to provide honest reports of their own dishonesty. This study sought to minimise the effect of this paradox by approaching the exploration of plagiarism using self-reports in combination with applied measures of students' understanding of the issue.

[1] The authors would like to thank the following University of Limerick academics for providing access to their classes; Dr Walter Stanley and Dr Michael Walsh (Faculty of Science and Engineering), and Dr Elaine Berkery (Kemmy Business School)

Data were analysed using Statistical Package for Social Sciences (SPSS) to identify significant differences between the students' responses based on their discipline and gender. Because of the ordinal nature of the data collected a non-parametric alternative to the *t*-test, the Mann-Whitney *U* test (Norusis, 2008) is used to test for significant differences between the groups studied. However, mean rather than median values of the students' responses are presented in Table 1 to provide a more meaningful insight into the different attitudes based on discipline and gender.

3. RESULTS

3.1 Overview of Data

Seven hundred and eight students participated in the study. The gender ratio of the overall sample was 39% female (N = 278) and 61% male (N = 429), with 37% (N = 266) studying engineering and 63% (N = 442) studying business. The majority of female students (87%) were taking business while the majority of male students (53%) were taking engineering.

How often do you engage in….[1]	**All**	**Male Engineers**	**Female Engineers**	**Male Business**	**Female Business**	***p*-value**
Copying text and inserting it in a paper without citation.	1.66	1.78	1.86	1.67	1.52	.007*
Copying an entire paper without citation.	1.15	1.21	1.22	1.16	1.07	.029*
Asking someone for (or buying) a paper and submitting it as your own.	1.20	1.26	1.17	1.24	1.11	.050*
Using the Internet to copy text and insert it in your paper without citation.	1.63	1.84	1.78	1.62	1.43	.000*
Using the Internet to copy an entire paper without citation and submitting it as your own.	1.13	1.20	1.22	1.12	1.06	.008*
Using the Internet to ask for (or purchasing) a paper and submitting it as your own.	1.10	1.18	1.19	1.05	1.06	.004*
You consider it wrong to engage in….[2]	**All**	**Male Engineers**	**Female Engineers**	**Male Business**	**Female Business**	***p*-value**
Copying text and inserting it in a paper without citation.	1.80	1.90	1.72	1.84	1.68	.127
Copying an entire paper without citation.	1.44	1.55	1.28	1.47	1.32	.077
Asking someone for (or buying) a paper and submitting it as your own.	1.45	1.52	1.42	1.47	1.35	.296
Using the Internet to copy text and insert it in your paper without citation.	1.76	1.85	1.69	1.84	1.63	.104
Using the Internet to copy an entire paper without citation and submitting it as your own.	1.36	1.48	1.19	1.35	1.28	.121
Using the Internet to ask for (or purchasing) a paper and submitting it as your own.	1.37	1.46	1.31	1.36	1.29	.280

Note 1: Scale 1 = *Never* to 5 = V*ery Frequently.*
Note 2: Scale 1 = *Strongly Agree* to 5 = *Strongly Disagree*
* Statistically significant, $p \leq 0.05$

Table 1: Summary Sample by Discipline and Gender (Mean values)

In Table 1 four groups of students are identified; Male Engineers (N = 229, 32%), Female Engineers (N = 37, 5%), Male Business (N = 200, 28%) and Female Business (N = 242, 34%). The summary of the sample is shown in Table 1 presents the mean responses to the two questions asked about each of the six scenarios presented to the students and also the results of an analysis of variance (ANOVA) between the four groups.

The questionnaire also asked students whether or not they had received any teaching on academic honesty, 42% of engineering students and 23% of business students answered that they had received such training.

The data presented in Table 1 suggest that there are differences between the four groups of students identified but that these differences relate to students' engagement in plagiarism rather that their ethical views. In other words, all students regardless of gender or discipline agree that plagiarism in wrong, whether or not the internet is involved, but despite this some students engage in plagiarism to a significantly higher level than others. A more detailed analysis of the data based on the three questions posed in the introduction follows.

3.2 Discipline based differences

Discipline based differences between engagement in and ethical views towards plagiarism are shown in Table 2. For each question the responses of all engineers are compared with those of all business (All). In addition, male engineers are compared with male business (Male) and female engineers are compared with female business (Female). The results confirm that there are no statistically significant differences between the ethical views of engineering and business students, but that there are differences between the levels of engagement of both groups. In five of the six scenarios presented engineering students are more likely to engage in plagiarism than business students. When this is broken down by gender fewer differences emerge. Male engineering students are more likely to use the internet for the purpose of plagiarism than male business students and female engineering students are more likely to copy text and insert it in a paper without citation (using the internet or not) than female business students.

	How often do you engage in….[1]			**You consider it wrong to engage in….[2]**		
	All	**Male**	**Female**	**All**	**Male**	**Female**
Copying text and inserting it in a paper without citation.	.008*	.330	.024*	.059	.342	.529
Copying an entire paper without citation.	.017*	.329	.132	.284	.928	.701
Asking someone for (or buying) a paper and submitting it as your own.	.234	.782	.813	.230	.908	.301
Using the Internet to copy text and insert it in your paper without citation.	.000*	.004*	.018*	.266	.959	.530
Using the Internet to copy an entire paper without citation and submitting it as your own.	.031*	.460	.131	.257	.549	.500
Using the Internet to ask for (or purchasing) a paper and submitting it as your own.	.001*	.002*	.316	.168	.552	.879

* Statistically significant, $p \leq 0.05$, Mann Whitney U Test

Table 2: Differences between engineering and business students (*p*-values)

In summary, the answer to Question 1 is; yes, there are differences between students' engagement in plagiarism based on discipline but; no, there are no differences in students' ethical views of plagiarism based on discipline.

3.3 Gender based differences

Gender based differences between engagement in and ethical views of plagiarism are examined in Table 3. For each question the responses of all male students are compared with those of all female students (All). In addition, male engineering students are compared with female engineering students (Engineers) and male business studies students are compared with female business studies students (Business).

	How often do you engage in….[1]			**You consider it wrong to engage in….[2]**		
	All	**Engineers**	**Business**	**All**	**Engineers**	**Business**
Copying text and inserting it in a paper without citation.	.035*	.498	.083	.055	.528	.254
Copying an entire paper without citation.	.039*	.961	.121	.002*	.134	.011*
Asking someone for (or buying) a paper and submitting it as your own.	.003*	.347	.007*	.131	.908	.151
Using the Internet to copy text and insert it in your paper without citation.	.000*	.477	.009*	.032*	.644	.061
Using the Internet to copy an entire paper without citation and submitting it as your own.	.045*	.959	.096	.046*	.150	.234
Using the Internet to ask for (or purchasing) a paper and submitting it as your own.	.290	.721	.397	.040*	.275	.178

* Statistically significant, $p \leq 0.05$, Mann Whitney *U* Test

Table 3: Differences between male and female students (*p*-values)

The data show that in all except one of the scenarios presented male students are statistically more likely to engage in plagiarism than female students. This difference is not seen within the engineering students where both male and female students are equally likely to plagiarise. But, male business students are more likely to engage in some forms of plagiarism than their female counterparts. Statistical differences are also found between the ethical views of male and female students, in four of the scenarios presented females are found to have higher ethical standards than males.

Based on this analysis the answer to Question 2 is yes, there are differences between students' engagement in and ethical views of plagiarism based on gender.

3.4 Internet based differences

To analyse the differences between students' engagement in and attitudes towards internet enabled and non-internet plagiarism their responses to the first three scenarios are compared with their responses to the second three scenarios. These comparisons are conducted within each of the four groups of students involved in this study and the results are shown in Table 4 below. Students are less likely to use the internet to ask for a paper to submit as their own, in other words they are more inclined to ask for papers using other means. Female business studies students are less likely to use the internet to copy text without citation. In terms of ethical views, students consider it more acceptable to use the internet to plagiarise than to use non-internet means.

These findings suggest that there are differences between students' engagement in and ethical views of internet based and non-internet based plagiarism, the answer to Question 3 is yes.

	All	Male Engineers	Female Engineers	Male Business	Female Business
How often do you engage in….[1]					
Internet vs non-internet copying text and inserting it in a paper without citation.	.266	.238	.206	.406	.039*
Internet vs non-internet copying an entire paper without citation.	.458	.464	.480	.441	.926
Internet vs non-internet asking someone for (or buying) a paper and submitting it as your own.	.000*	.028*	.414	.000*	.114
You consider it wrong to engage in….[2]					
Internet vs non-internet copying text and inserting it in a paper without citation.	.184	.346	.635	.721	.170
Internet vs non-internet copying an entire paper without citation.	.002*	.090	.236	.026*	.349
Internet vs non-internet asking someone for (or buying) a paper and submitting it as your own.	.000*	.132	.326	.013*	.033*

* Statistically significant, $p \leq 0.05$, Mann Whitney U Test

Table 4: Differences between internet enabled and non-interned plagiarism (*p*-values)

5. DISCUSSION

Analysis of the data (Table 1) shows that overall, students across the sample declare to hold high ethical views regarding plagiarism, and report low levels of engagement in such behaviour. This result is very similar to the level of reported use of uncited online and printed sources found by Rettinger and Kramer (2009) and Scanlon and Neumann (2002). The measures used in this study were taken from Scanlon and Neumann (2002) allowing a direct comparison of results. The results from the Irish study were lower than those reported by Scanlon and Neumann, for example, the mean value reported for copying text and inserting it without citation in the Scanlon and Neumann study was 2.04, compared to 1.66 in this study. The other measures follow a similar trend. This finding suggests that the students who participated in this study report lower rates of engagement in plagiarism than the participants in other studies.

Findings according to gender are consistent with much of the existing literature. Academic offences tend to be more ethically acceptable to males as reported by Underwood and Szabo (2003) and Whitley (2001). Also, female students were significantly less likely than males to report that they would engage in dishonest educational practices, according to findings by Elzubeir and Rizk (2003), Genereux and McLeod (1995), and Newstead et al. (1996). Interestingly, we found indications that moral beliefs play an important role in women's plagiarism intentions, while it does not seem to be such an issue for males, as also argued by Tibbetts (1997, 1999). The authors attribute this tendency to higher levels of anticipated shame among women and less self-control among men, which accounted for most of the variation in cheating intentions between women and men.

Regarding discipline, we have noted that engineering students were more likely to have engaged in plagiarist behaviour than business students despite the fact that almost twice as many engineering students claim to have received training in academic honesty. This is consistent with findings elsewhere indicating that reported cheating was more common in science, technology and engineering students than those in other disciplines (Carpenter, et al., 2006; Newstead et al., 1996). However, the ethical views of engineering students were no different than the views of business students suggesting a dissonance between what engineering students believed and what they actually did. Engineering students are also significantly more likely to use the internet to engage in plagiaristic behaviour, this could possible be due to the fact that engineering students are more comfortable with the use of technology.

6. CONCLUSIONS

The findings discussed here have painted a descriptive and preliminary picture of a complex reality, without making assumptions of causal relationships between variables. Male students and engineering students are more likely to engage in plagiaristic behaviour than female or business students, this is broadly in line with the results of previous studies. The findings seem to point to the need for further attention to plagiarism policies in both engineering and business courses, and its likely relation to writing and literacy skills. This is relevant in the context of a curriculum that promotes transferable skills across all disciplines. Specifically the training on academic honesty received by engineering students needs to be examined.

While we have contributed with some additional evidence to the narrow body of literature existing on discipline-specific views and behaviours on plagiarism, much remains to be done to explore the underlying variables that may explain the blatant differences found.

Further research must also address lecturer perceptions and teaching approaches to plagiarism prevention by discipline, as it is likely that these factors have a strong influence on students' behaviours and views.

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THE FORMATIVE VALUE OF PEER FEEDBACK IN PROJECT BASED ASSESSMENT

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Abstract: This Study investigates the impact of peer feedback used as an instructional strategy to enhance undergraduate student learning in project based coursework. While peer feedback has been demonstrated to support students' learning in traditional classrooms, little is known about the efficacy in a project based learning environment. This study aims to examine undergraduate students' perceptions of the value of giving and receiving peer feedback, specifically related to a project based learning activity. In addition, the impact of that feedback on students' satisfaction with the project based module they undertook and on their thinking skills, based on Bloom's taxonomy, was also investigated. In order to explore this impact a comparative analysis was conducted with a concurrently running module that they completed which acted as the control. Results suggest that the quality of students' reflections through peer feedback and overall satisfaction with the module remained high despite students' preference for instructor feedback. Students noted that peer feedback can be valuable and, more importantly, described how giving feedback not only reinforced their learning but enabled them to achieve greater awareness of the strengths and weaknesses of their own project.

Keywords; peer feedback, project based learning, student perceptions, engineering education.

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1. INTRODUCTION

1.1 Forms of Assessment

It is commonly accepted that there are two main rationales for the inclusion of assessment in education: a) for certification (or summative) reasons and b) for learning (or formative) purposes (Liu and Carless 2006). The former is often highlighted as dominant in higher level education (Knight 2002), especially in an Irish context which employs a matriculation system which predominantly (often exclusively) charges summative assessment, in the form of the Leaving Certificate, with the responsibility of allocating university places to students. With such emphasis placed on assessment for accreditation at second level (high-school) it is not surprising that students are frequently being reported as driven by a natural desire to achieve high grades (Ryan, Irwin et al. 2004). However this form of assessment is primarily focused on the certification of students and is often based on the erroneous but widespread assumption that students can later transfer these skills and information with ease. Research has shown that this can lead to adverse consequences such as surface learning, with the inauspicious result that students find it hard to apply what they have learned to real-life problems and scenarios (see Gunderman, Williamson et al. 2003). The authors of this paper are currently involved in the design and implementation of undergraduate modules which, whilst acknowledging the dominance of the summative paradigm, seek to place greater emphasis on the purpose of assessment related to the promotion of learning. This emphasis on assessment for the promotion of learning is supported by the pedagogical context in which it manifests, in this case a pedagogical environment based on constructivism and discovery learning.

1.2 Educational Context

Problem and project based learning (PBL) has rapidly been adopted by many institutions of higher education as the foundation of their educational concept (see Prince and Felder 2006). However the successful implementation of PBL requires more than the modification of existing curricula, but a change in teaching and learning strategies and in the approach to assessment, a principle given credence to by Barron et al. (1998, p. 271). For the purpose of this initiative a prior traditionally taught module on manufacturing processes was adapted and in many ways ameliorated to incorporate a significant project-based element. Students were assigned a design challenge where they were required to conceive, design and manufacture a model motorcycle incorporating different processes with specific emphasis placed on joining processes. By incorporating design and a project-based element worth 75% of the module, the authors aimed to promote the development of autonomous learners capable of self-evaluation and peer appraisal. However it was clear from the genesis of this initiative that traditional assessment practices, that encouraged particularised and 'rote' learning, would conflict with the aims of the newly developed curriculum, as highlighted by Sluijsmans, Dochy et al. (1998). As a result new pedagogical and assessment approaches were developed which included the development of E-portfolios to support students' projects and the use of peer feedback through these portfolios, as well as in the workshops during the manufacture of the projects. To ensure that students engaged in the peer feedback process, up to 5% was awarded based on the quality of students' responses. However it was clear from subsequent evaluation that most students were intrinsically motivated to critique and provide support through feedback for their peers (as discussed later in the paper). Students' fervour and support for the peer feedback process was however to a large extent reliant of the security provided by the E-portfolio system which logged every students design idea and creative development as well as the feedback provided to their peers on their designs and concepts. As the time and date of each update to the students E-portfolio and any feedback provided were logged, students felt secure in the knowledge that any plagiarism could be traced and addressed accordingly. This helped develop a collaborative and collegial approach to learning, which is lacking in traditional practical modules, as highlighted by one student:

"I like the fact that you could trace the ideas and designs for the bike back to the original owner so I wasn't afraid to share my ideas with the rest of the class as long as I had it uploaded onto (the E-portfolio) first".

2. RATIONALE

2.1 Peer Feedback and Assessment

Falchikov (1995) defines peer assessment as the process whereby groups of individuals rate their peers. However Falchikov's definition is principally concerned with the grading of students and therefore simply describes peer assessment for accreditation purposes and discounts its formative value for both the assessor and the recipient. Somervell (1993) found that peer assessment engages students in making judgements about the work and/or the performance of their peers. This study and many others since (see Sluijsmans, Dochy et al. 1998; Boud, Cohen et al. 2001) have shown that by engaging in this decision making process it helps students develop into 'reflective practitioners' who are capable of not only reflecting critically on the work of others but also on their own professional practice. It is understood that in this formative capacity peer assessment provides greatest support for the development of 'life-long learners' capable of critically evaluating tasks and their own performance, thus enabling students to reflect on their role in the learning process. It is this role therefore that the authors envisaged peer assessment playing in the learning process of students. In order to assure that the focus of the peer assessment process remained directed towards the formative value of appraisal, for this module students were not required to rank each other but to continuously observe and evaluate each others' designs and projects. Students were then capable of providing critical feedback through a Blog available on their E-portfolios. While all students involved in the module could access each others' E-portfolios, students were further stratified into groups of four where each student was accredited with the responsible of critically evaluating other students in the group. It is important to note however that students wilfully went beyond what was outlined in the module requirements and provided feedback to many other students in the class.

2.2 Traditional Assessment versus Peer Assessment and Feedback

Bourdieu (1998, p. 20) metaphorically employed the image of physicist James Clerk Maxwell's demon to aid in his portrayal of traditional education. A similar analogy could be applied to traditional assessment practices. In explaining how the Second law of Thermodynamics could be suspended, Maxwell (1872, p.4) imagined a container divided into two portions; *A* and *B*. Both parts of the vessel contained the same gas at approximately equal temperatures. He then imagined a demon that could see the moving particles in the vessel, some being warmer, therefore faster moving, others cooler, therefore slower moving. By opening a small door the demon sends the fastest particles into container *A* and the slower particles into container *B*. The demon thereby maintains difference that would otherwise tend towards equilibrium. Traditional summative assessment practices act like Maxwell's demon, rewarding students with a specific set of skills; logical-mathematical and linguistic skills, and the ability to recall information, often to the detriment of those with alternative skills such as: spatial intelligence, intrapersonal and interpersonal aptitude.

Recognising this and the work of Howard Gardener (1993) on Multiple Intelligences, the authors aimed to design a structure for assessment that respected the varying skill sets that students possess. Students were set tasks and graded on these tasks at different stages of the manufacture of the motorcycle, from initial concepts and designs, to successful incorporation of different joining processes, and right through to the completion of the model. The E-portfolios allowed students to express their designs, ideas and themselves through a variety of media, graphical sketches, working drawings, audio and visual accounts, and through written reports and blogs. Students were also presented with continuous feedback from their peers and module lecturer at designated points in the module upon completion of set tasks. However in acknowledgement of the dominance of summative assessment in traditional education structures and students' prior educational experiences, the final 20% of students' grades was allocated to the completion of a written examination at the end of the semester.

3. METHODS

3.1 Procedure for Peer Feedback

47 undergraduate students undertook the completion of this module. While each student was required to design and manufacture a model motorcycle of their own, they were also assigned to groups, eleven groups of four and one group of three students, for the purpose of providing peer support, guidance and feedback. The only restriction given to the students regarding the model motorcycle was in relation to its size. The model was restricted to a maximum dimension of 600mm between wheel axles. By providing very little restrictions to the model parameters it was envisaged that this would remove any limitations on students' creative freedom and exploit their natural competiveness. As highlighted by Sydow, Lindkvist et al. (2004), the development of a learning environment which nurtures students creative endeavors is central to the philosophy of project-based learning, "It is a matter of freedom with responsibility, where creative and innovative activity is both a possibility and a duty" (Sydow, Lindkvist et al. 2004, p. 1480). By providing students with as little didactic instruction as possible, students were encouraged to draw on their previously developed repositories of knowledge as well as expanding their knowledge and skills to solve new problems.

For the purpose of recording and disseminating students feedback a blog was created on each student's e-portfolio onto which students could post their recommendations, evaluations and comments of support for their peers. It also provided a medium for students to discuss and share ideas. However this was not the only media through which the groups could interact and provide feedback. Students were also required to provide support to other group members in the workshop throughout the course of manufacture of the models. In order to monitor this process each group was requested to nominate a group leader who was assigned the responsibility of reporting back to the module lecture and/or teaching assistant on a regular basis.

3.2 Analysis of Peer Feedback Impact

Traditional summative assessment practices evaluate students' knowledge of the subject area, i.e. their ability to learn, recall, list and recite factual content (Broadfoot 1996). However through the structure outlined for this primarily project-based curriculum, it is envisaged that it will help promote a shift away from convergent student thinking with one single solution based principally on subjective experience. Is it hypothesised that the peer feedback process, in conjunction with the design initiative implicit to this project-based module, would help students see possible alternative solutions, as well as incorporating individual insights, previous knowledge, past observations and their owns subjective experiences in the final project. Therefore the pedagogical approach employed in this study aims to stimulate divergent student thinking.

In order to assess the success of this approach and the impact of the peer feedback process on students' judgments and reflections of their own work, Bloom's

Taxonomy for the cognitive domain was applied (Bloom 1956). From most demanding to least, Bloom' cognitive objectives are as follows:

- **Evaluation** – Shows the ability to judge the value of material for a given purpose based on definite criteria and rational. Includes decision-making and selection.
    - **Evidence**: Assessments, critiques and evaluations
- **Synthesis** – Recombines the parts created during analysis to form a new entity, different from the original.
    - **Evidence**: Creative behaviour such as the development of new solutions.
- **Analysis** – Breaks down material into its constituent parts so that its organisational structure can be understood.
    - **Evidence**: Breaking down, categorising, classifying, and differentiating.
- **Application** – Uses information, principles, and theory learned to answer a question, solve a problem or complete a task.
    - **Evidence**: Conceptual activities such as application, classification and development.
- **Comprehension** – Awareness of what the material means, allows one to demonstrate an understanding of the material based on prior knowledge.
    - **Evidence**: Demonstrate comprehension by applying comparisons and/or contrasts.
- **Knowledge** – The recall of previously learned material, of simple facts or complete theories. Bringing to mind appropriate information.
    - **Evidence**: Definitions and outlines. Reproduction of requisite knowledge.

4. IMPLEMENTATION OF THE FEEDBACK PROCESS

A well designed and automated peer feedback process can fail to produce meaningful results if care is not taken during its implementation. To begin with it is essential that both the feedback providers and recipients be acquainted with how the feedback process should work and in the case of the E-portfolios how the blog system operates. As highlighted by McGourty et al. (1998) it is important that the instructor takes the time to discuss the feedback process with the students, as the students need to be aware of the rationale for receiving feedback from their peers. Additionally, it is essential that the students understand how the competencies being measured are linked to the module objectives. Otherwise the validity of the students' feedback comes into question. Therefore without restricting the scope of the module it is important that all involved are clear about what its aims and objectives are prior to the introduction of the feedback process.

McGourty et al. (1998) also highlights the importance of instructor involvement in the feedback process. Students may receive peer feedback that contradicts their initial plans or designs and may wish to discuss this with an instructor. As a result the authors have made themselves available to students and in some cases facilitated group discussions with their peers in order to help them better understand the feedback they were receiving and the rationale behind that feedback. Feedback on their progress was also provided to students from an early stage in the module allowing them adequate opportunity to react to the feedback they received and implement any improvements required. Instructor feedback was provided as early as week three in the module and peer feedback had commenced the previous week. Students were informed that a significant proportion of their grades were allocated to their ability to assimilate this feedback and respond accordingly.

5. RESULTS

5.1 Development of Higher Order Thinking

Through the incorporation of the peer feedback initiative, and in collaboration with instructor feedback and the use of E-portfolios, this study aimed to develop students' higher-order thinking skills and engage them at elevated levels of Bloom's Taxonomy. Hopson et al. (2001) defines higher-order thinking skills as those cognitive skills that allow students to function at the analysis, synthesis, and evaluation levels of Bloom's Taxonomy. It is clear that as students progressed in the module a significant evolution in their thinking skills was evident in the reflections they posted and in the feedback they provided to their peers. In order to evaluate the thinking skills of the students, this study employed the use of repeated observations of students' reflections at three distinct phases of the module (weeks 2, 6 and 11 of a twelve week module). The observations were qualitative and therefore have a degree of subjectivity; however identical criteria were applied to all students and at all three phases of the study. Similar observations were previously employed by Athanassiou et al. (2003) in order to monitor the development of students thinking skills. The degree of cognitive sophistication as outlined by Bloom's Taxonomy is summarized in Appendix A for each student at all three stages of investigation. The student achievement was coded as follows: knowledge = 1, comprehension = 2, application = 3, analysis = 4, synthesis = 5, and evaluation = 6. Finally, an average score for each student was calculated for each stage of the study. Therefore, for example, a student who demonstrated cognitive aptitude at all six levels of Bloom's Taxonomy would achieve the maximum average score of 3.5. To determine whether or not the class as a whole demonstrated greater use of higher-order thinking skills and an improvement in cognitive sophistication, an average of all students' results was taken as an estimate.

On average the cognitive sophistication of the class was shown to advance throughout the duration of the module, with students typically operating at higher levels of Bloom's Taxonomy at successive phases of the study. Students' cognitive development, evident in their reflections, was shown to be greatest from assessment one in week 2, to assessment two in week 6 of the study, with an increase from 1.5 to 2.1 respectively (see appendix A). The development observed between the reflections made in week 6 by the students and those made in week 11, at the end of the project, are less apparent. However it is to be noted that on average most students demonstrated some higher-order thinking skills, as defined by Hopson et al. (2001), from a very early stage in the project. This was expected, as the project-based structure to the module requires by its very nature the analysis of a brief and the design of possible solutions. It is clear therefore that although students may already be operating at higher levels of Bloom's Taxonomy, through the use of apposite instruction and constructive feedback students can develop and apply higher-order thinking skills. However what is less apparent is the influence of instructor feedback over peer feedback in this development. Students received instructor feedback at two points during the completion of the project, at the end of weeks 3 and 9. By comparison, from the end of week 2 onwards, the peer support and feedback process ran concurrent to the manufacture of the project throughout the length of the module. In order to determine the impact of both the instructor and peer feedback process a semi-quantitative analysis of students' experiences of the module was conducted post completion. The module was also compared to a control module that the student completed in parallel, which while also incorporating E-portfolios for students did not include a peer feedback element and relied entirely on instructor feedback.

5.2 Survey on Students' Perceptions of the Module

During the final week of the module students were asked to complete a survey on their perceptions of the module. The survey was completely anonymous and required the students to rank, using a likert scale, different aspects of the module such as the pedagogical approach utilised, its aims and objectives, its structure and overall effectiveness. At the end of the survey students were also asked to provide some qualitative feedback about their experience of the module. While on average the class score never fell below 3.8 out of a possible 5 on the likert scale for any aspect of the module evaluated in the survey, what is more informative is the comments provided in the qualitative section of the survey. It is clear from students' comments that they enjoyed the project-based structure of the module:

> Great module, very enjoyable. The project was very testing but also educational. Enjoyed learning how to weld and throughout the semester the atmosphere in the labs was great. (Student 17)

> I enjoyed the module, thought it was a good learning experience and one that was thought well with a unique approach. (Student 28)

However it is also clear from the students feedback that they felt the module occupied too much of their time and took from other modules running in parallel. This will be a contributing factor to their performance and perceptions of the control module used for comparison in this study and discussed later in this paper.

> The module was very interesting and very enjoyable but definitely led to neglect for other modules. (Student 14)

> I found that work on the bike could have continued on and on. I don't believe that our course work should interfere with our studies. (Student 1)

It is clear then that the project-based structure to the module was successful in its attempts to engage students in the learning experience. However based on students' comments and observations made in the workshop it can also be concluded that the lack of didactic instruction and of defined limitations to the design of the model motorcycle led to students not knowing when the model was finished. There were constant improvements that could be made to the design and a sociable but competitive environment developed as a result with each student driving the next. The peer feedback element to the module also emerged as a contributing factor to this:

> I found the input from other members of the class very useful. While I didn't agree with some of their comments it was definitely good to get a different persons' perspective at times. (Student 21)

> I thought the peer feedback part to the module was very good, but I would have liked more feedback from the lecturer at time so that I knew how I was doing in the module. (Student 2)

The views of student 2 were echoed by many other students. While each student was proved with individualised instructor feedback twice during the completion of the module, this feedback was entirely qualitative and aimed at highlighting areas of success and areas where improvements were necessary in the students' designs. Instructor feedback was structured in this manor in order to maintain the formative focus of assessment for the module. However due to the impact of operant conditioning as a result of previous assessment models experienced by students, they often requested a grade from the instructor upon receipt of qualitative feedback.

5.3 Comparison with Control Module

Although both modules employed the use of E-portfolios and had a significant project-based element, students appeared less engaged with the control module. The subject area of the control module was technical graphics and although the project element was not workshop based, it did require the development and implementation of similar design and creativity skills on the part of the students. Feedback was instructor driven and the module did not include a group-work element. Students' provided much fewer records on their E-portfolio throughout the module and their reflections demonstrated primarily lower-order thinking skills when compared to those entered for the peer feedback module. As highlighted by the student's comments it is clear that the work on the motorcycle project lead to the "neglect" of alternative modules and coursework. However it is also clear that the peer feedback and open access E-portfolios utilised in the experiment module lead to the development of a positive but competitive environment, which in turn had a positive influence on learning outcomes. This was not only evident in the levels of engagement of the students but also in their overall grades for both modules, with students performing significantly better in the experiment than in the control module.

6. CONCLUSIONS

A development in the cognitive sophistication of students' reflections was evident as students progressed through the module. The greatest shift towards higher order, critical thinking occurred early on in the first half of the module, shortly after the receipt of initial peer and instructor feedback. This suggests that qualitative feedback of this nature can have immediate impact on the thinking skills of students. By offering students the opportunity to critic each others work, it encourages them to reflect more on their own project and design. This strategy automatically encourages students to intuitively engage at the higher levels of Bloom's Taxonomy.

The use of both a significant project-based and peer feedback element to the module, along with formative assessment methods, facilitated in the development of a positive, sociable, but competitive environment where students constantly strive to enhance their designs and projects. It was successful in not only delivering the course content but in thoroughly engaging the students. However this was often to the detriment of alternative modules that the students were involved in, with students dedicating an unbalanced percentage of their time to the completion of the project. In order for similar pedagogical strategies to be sustainable, a united and 'over arching' teaching and learning approach to the development of undergraduate courses must be established. While this approach was successful for this module and class of 47 students, more research is required into the implications of similar teaching strategies for alternative curricula and subjects with diverse student numbers.

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Appendix A

Quality of Student Reflections According to Bloom's taxonomy Levels

	Week 2							Week 6							Week 11						
	Bloom's Level						Student Average Score	Bloom's Level						Student Average Score	Bloom's Level						Student Average Score
Student	1	2	3	4	5	6		1	2	3	4	5	6		1	2	3	4	5	6	
1	1	2	3	4			1.7	1		3	4			1.3	1	2	3	4			1.7
2	1	2	3	4	5	6	3.5	1	2	3	4	5	6	3.5	1	2	3	4	5	6	3.5
3	1	2	3				1.0	1	2	3	4	5		2.5	1	2	3	4	5	6	3.5
4	1	2	3				1.0	1		3	4			1.3	1	2	3				1.0
5	1	2	3	4			1.7	1	2	3	4	5		2.5	1	2	3		5		1.8
6	1	2	3	4			1.7	1	2	3	4	5		2.5	1	2	3	4	5		2.5
7	1						0.2	1						0.2	1	2					0.5
8	1	2	3				1.0	1	2		4	5		2.0	1	2	3	4	5		2.5
9	1						0.2		2					0.3	1	2	3				1.0
10	1	2	3	4			1.7	1	2	3	4	5		2.5	1	2	3	4	5		2.5
11	1	2	3	4		6	2.7	1	2	3	4	5	6	3.5	1	2	3	4			1.7
12	1	2	3				1.0	1	2	3				1.0	1	2	3				1.0
13	1	2	3				1.0	1	2	3	4			1.7	1	2	3	4			1.7
14	1	2	3				1.0	1	2	3	4			1.7	1	2	3				1.0
15	1	2	3	4			1.7	1	2	3	4	5		2.5	1	2	3	4	5		2.5
16	1						0.2	1						0.2	1	2					0.5
17	1	2	3	4			1.7	1	2	3	4			1.7	1	2	3	4			1.7
18	1	2	3	4			1.7	1	2	3	4	5		2.5	1	2	3	4	5	6	3.5
19	1	2					0.5		2					0.3	1	2	3				1.0
20	1	2	3				1.0	1	2		4	5		2.0	1	2	3		5		1.8
21	1	2	3	4			1.7	1		3	4	5		2.2	1	2		4	5		2.0
22	1	2	3	4			1.7	1	2	3	4		6	2.7	1	2	3	4	5	6	3.5
23	1	2	3	4	5		2.5	1	2	3	4	5		2.5	1	2	3	4	5		2.5
24	1		3	4			1.3	1	2	3	4			1.7	1	2	3	4			1.7
25	1	2	3	4	5		2.5	1	2	3	4	5		2.5	1	2	3	4	5		2.5
26	1	2	3				1.0	1	2	3	4	5		2.5	1	2	3	4	5		2.5
27	1	2	3	4			1.7	1	2	3	4			1.7	1	2	3	4			1.7
28	1		3	4			1.3	1	2	3	4	5	6	3.5	1	2	3	4	5	6	3.5
29	1	2	3	4	5		2.5	1	2	3		5	6	2.8	1	2	3	4			1.7
30	1	2	3				1.0			3	4	5		2.0	1	2	3	4	5		2.5
31	1	2	3				1.0	1		3	4	5		2.2	1	2	3	4	5		2.5
32	1	2	3	4			1.7	1	2	3	4			1.7	1	2	3	4			1.7
33	1	2	3				1.0	1		3	4			1.3	1	2	3		5		1.8
34	1		3	4			1.3	1	2	3		5		1.8	1	2	3	4			1.7
35	1	2	3	4			1.7			3	4	5		2.0	1	2	3	4	5	6	3.5
36	1	2		4	5		2.0	1	2	3	4	5	6	3.5	1	2	3	4	5		2.5
37	1	2	3				1.0	1	2		4	5		2.0	1	2	3	4			1.7
38	1	2	3	4			1.7	1	2	3	4	5		2.5	1	2	3		5	6	2.8
39	1	2	3	4			1.7	1	2	3	4			1.7	1	2	3	4			1.7
40	1	2	3		5	6	2.8	1	2	3	4	5	6	3.5	1	2	3	4	5	6	3.5
41	1	2	3				1.0	1	2	3				1.0	1	2	3	4			1.7
42	1	2	3	4	5		2.5	1		3	4	5	6	3.2	1	2	3	4	5	6	3.5
43	1	2	3	4	5		2.5	1	2	3	4	5		2.5	1	2	3	4			1.7
44	1	2	3	4			1.7	1	2		4	5	6	3.0	1	2	3	4	5		2.5
45	1	2	3	4			1.7	1	2	3	4	5		2.5	1	2	3	4	5	6	3.5
46	1	2	3		5		1.8	1		3	4	5	6	3.2	1	2	3	4	5	6	3.5
47	1	2	3	4			1.7	1	2	3	4	5		2.5	1	2	3	4	5		2.5
Class Average							**1.5**							**2.1**							**2.2**

ACCELERATING CAMPUS ENTREPRENEURSHIP (ACE):

A SECTIONAL ANALYSIS OF PRACTICES TO EMBED ENTREPRENEURSHIP EDUCATION INTO ENGINEERING AT IRISH HIGER EDUCATION INSTITUTIONS (HEI's)

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ABSTRACT:

Aims: Accelerating Campus Entrepreneurship (ACE), a Strategic Innovation Fund collaboration, aims to produce technology graduates who would not only have the entrepreneurial competencies to be more creative and self-confident in their careers but in time to create new technology start-ups and become employers in the innovation economy[1]. This paper investigates the cross-campus approach to facilitate entrepreneurship opportunities for engineering students in a way that leverages the commercial competencies of campus innovation centres, the management competencies of the Business School and the [2] technology development competencies of the Engineering School.

Content: Previous research conducted by ACE on a case-study basis in Ireland's institutes of technology and universities took a multi-stakeholder perspective from students, academics, institute management, technology transfer offices and industry[1]. While the individual cases were useful, their cross-referencing provides a valuable benchmarking insight into the provision of entrepreneurship education to engineering students on which ACE could develop pilot programmes. The paper, therefore, focuses on profiling practice rather than advancing theoretical models of empirical research.

Conclusions: Developing educator competencies and institutional leadership needed to 'mainstream' entrepreneurship within engineering provides the principle challenge. Furthermore, entrepreneurship education is often misconstrued as being about creating graduate entrepreneurs and start-ups as opposed to entrepreneurial graduates. Many pedagogical tools were identified, yet the 'business-plan', remains the primary underpinning, making it difficult for engineering students to see it in a wider contextual relevance that stimulates entrepreneurial behaviour and fosters mindsets. Yet, despite these challenges, integrated programmes of entrepreneurship education within the technology disciplines are gaining momentum, which over time could lead to generational change both for graduates and for the societal roles of their educational institutions.

1. INTRODUCTION

The provision of entrepreneurship education in Ireland for engineering students has gained momentum in recent years[3]. Against an array of campus initiatives such as incubation centres, technology-transfer resources, enterprise competitions, internships and clubs, it is becoming more common to hear calls for the integration of entrepreneurship within technical disciplines such as engineering. This evolution in academic entrepreneurship raises urgent questions for engineering educators to ensure their programmes remain relevant and contemporary without diluting technical rigour.

1. What is the rationale for embedding entrepreneurship education into engineering?
2. What exactly is an “integrated” entrepreneurship program?
3. What are the challenges, benefits and costs involved in moving outside spheres of instruction traditionally owned by the business school?
4. What are the priority learning outcomes and appropriate pedagogical tools?

This paper informs the discussion of such questions by reviewing the evolution towards integrated programs, by developing a conceptual framework for models of delivery and presenting a detailed discussion of best-practice case-studies both in Ireland and abroad. With the legendary dorm-room genesis of student start-ups, such as *Facebook* and *Yahoo*, pervading the consciousness of almost every engineering student, most HEI’s have now in place the much needed "role-models" to inspire young entrepreneurs[4], of which more and more now find it plausible to explore the start-up avenue in these recessionary times.

2. SO, WHY BOTHER?

Engineering programmes focus on applied sciences, often a mile deep and a micron wide, leaving students unprepared for careers at the interface of business and science[5]. Entrepreneurship education can be beneficial for graduates and their employers with entrepreneurial graduates starting more businesses, developing more products and making more money than their peers[6,7]. Entrepreneurship educators can point to engineering students working in cross-disciplinary teams on business-plans, some of which evolve into going-concerns underpinned by innovative technologies. Students themselves are interested in entrepreneurship irrespective of discipline because it is serves long-term career goals, enabling them to be flexible in the workplace[8]. For engineering graduates, successful careers tend to be linked with “entrepreneurial” behaviour. Whether to win support for technology projects or to acquire resources outside their control for new opportunities, entrepreneurial skills are critical to bringing products from scientific research into industrial application.

In the US enterprising students contribute 6–8% GDP through their business start-ups[9]. UK technology graduates founded 70% of fast-growth companies, contributing £4bn in sales 2004-2007 and employing 38,000 people[10]. Similarly, many of Enterprise-Ireland’s high potential start-ups (HPSU’s) are technology driven. Yet, despite a recent €40m investment in campus incubation facilities, “spin-outs” from academia remain the exception,[11] highlighting the absence of cross-campus links. Over €1bn has been invested in research through Science Foundation Ireland since 2001[12]. Policy advocates insist that third-level research will create economic value through commercialisation in strategic areas relevant to economic development while detractors cite disappointing returns[13], highlighting the need for this “science-push” approach to be supported by a human capacity for entrepreneurship[14]. A related issue is the mismatch between graduate skills and employer requirements. ABET, the US accreditation body, highlights the ability “to function in cross-disciplinary teams” and "communicate effectively", "manage uncertainty" and "problem formulation"[15] as critical skills. With the Celtic Tiger having created an acute skills gap for HPSU's, graduate skills now require adjusting to new circumstances. While engineering graduates in the 1990's could step into an easy berth with a multinational, entrepreneurial graduates who can deal with job uncertainty and likelihood of self-employment are now required. The role of higher education institutions, too, is changing[16] with pressure on them to[17]:-

1. make widely accessible their IP for commercial exploitation through activities such as strategic research, patenting, licensing, spinouts and technology transfer;
2. impact more on economic development and societal needs, e.g. producing graduates with relevant skills, striving for less reliance on public purse, creating an innovation culture, fostering entrepreneurial mindsets and supporting a growing interest in corporate and social entrepreneurship;
3. support technology-based firms through business incubation programmes, consulting, industrial training and solving complex real-world business problems.

From an engineering educator perspective, there are many reasons why "entrepreneurial skills" are more important now than in the past. Globalisation and project complexity have induced companies to use matrix structures in which project managers must leverage "moral" forms of authority. Customers are more demanding and market economics has become the driving force behind decision making. Product life-cycles are much shorter, making it essential to recognise opportunities and take advantage of them as soon as they arise. This is the context in which the entrepreneurial mindset plays a role in enabling engineers to show initiative, think creatively and acquire resources outside their control. Producing engineering graduates for a European innovation economy is also a competitive imperative and, while scientific and occupational skills of Europe's graduate engineers are adequate, skills needed for global competiveness lag those of competitor economies[18].

3. METHODOLGY

There were four broad steps in the investigation carried out by the ACE research team.

1. An Analysis of Academic Entrepreneurship in Higher Education in Ireland;
2. Soliciting Feedback from Entrepreneurs and Employers;
3. Gathering of International Case-Based Evidence;
4. Development of Pilot Engineering Entrepreneurship Programmes;

Interviews with four distinct offices or roles across the higher education sector: president, head of engineering school, an entrepreneurship lecturer, industrial liaison or technology transfer manager: were used to cross-reference data on key areas such as teaching and learning, resources, strategy, policy, culture, multidisciplinary approaches, technology commercialisation[19]. In addition, a survey of engineering students from the five ACE partner institutions explored their attitudes towards entrepreneurship (Table 1).

Institution	Engineering Discipline	Students 08/09	Students 09/10
DKIT	Civil, Electrical Mechanical	147	63
ITB	Computer and Mechatronic	48	40
CIT	Biomedical Engineering	15	27
NUIG	Various Engineering	35	17
	Total	**285**	**147**

Table 1: Engineering Students Surveyed at ACE Institutions

The survey investigated: entrepreneurial interest and aptitude; influences; motivations for starting a business; skills development and current curricula provision. The second step explored the entrepreneurial skills required of graduates. A review of academic literature reinforced by a survey of 33 companies investigated questions pertaining to entrepreneurial competencies; the anticipated benefits of entrepreneurial employees; the methods for fostering skills; and the importance of enterprise linkages. The third step identified best-practice exemplars, three of which were examined in detail: the Northern Ireland Centre for Entrepreneurship, UK National Council for Graduate Entrepreneurship and the University of Satakunta. In addition, US models of technology entrepreneurship education were examined. The final step currently involves a deconstruction of engineering programmes into a conceptual framework that broadly classifies the extent of their integration and, subsequently, the development of pilot engineering programmes that embed entrepreneurship education.

4. FINDINGS

4.1 CURRENT OPPORTUNITIES FOR ENGINEERING STUDENTS

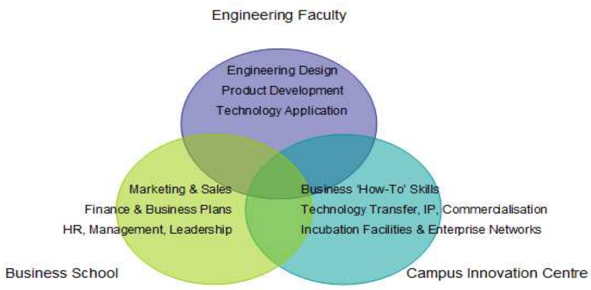
ACE found that 50% of engineering disciplines included entrepreneurship, the overriding pedagogical underpinning being the stand-alone business-plan module. Yet, evidence suggests that successful entrepreneurs depend more on their ability to adjust quickly and less on formal business planning. Worse, the strong focus on functional management, such as marketing and finance, weakens the potential for entrepreneurship to be valued by engineers. ACE also found that only a small number of supporting pedagogies are used, mainly cases studies, lectures, project work and venture simulations despite the fact that entrepreneurial learning needs to be experiential if behaviours and skills are to be nurtured. Access to entrepreneurs as role models in the classroom was also reported as an issue.

4.2 GROWING THE ENTREPRENEURIAL CULTURE

While 75% of students indicated that they would be interested in starting their own business in the future, a common problem identified in growing that interest is the lack of enterprise culture on campus. Consequently, they view entrepreneurship as primarily being about ‘business’, which undermines their sense of engineering identity. A co-requisite to entrepreneurship curriculum, therefore, is the development of entrepreneurial activities that broadens its contextual relevance. Yet, the status-quo of such activities in Ireland remains heavily directed towards business students. Enterprise-Ireland’s Student Awards and Newstalk’s Enterprise Competition, for example, both have their origins in traditional business-plan and case-study approaches. Consequently, ACE has hired a student entrepreneurship intern in each of the partner institutions to roll-out a suite of extra-curricular activities. Funded by the county enterprise boards, these part-time roles pursue the wider engagement of students in enterprise-related activities and the promotion of entrepreneurship amongst peers[20].

4.3 ORGANISATIONAL STRUCTURE & EDUCATOR COMPETENCIES

Entrepreneurship is a team-sport that requires cross-disciplinary input. Its holistic nature is, therefore, directly at odds with the functional structures of faculty and their programmatic offerings. While engineering entrepreneurship is best owned by the Engineering faculty, it is most effective when it engages the wider expertise on campus to enhance student learning (Dia. 1). Appropriate inputs on marketing, finance, and business-plans from Business faculty can significantly enhance any engineering entrepreneurship programme.



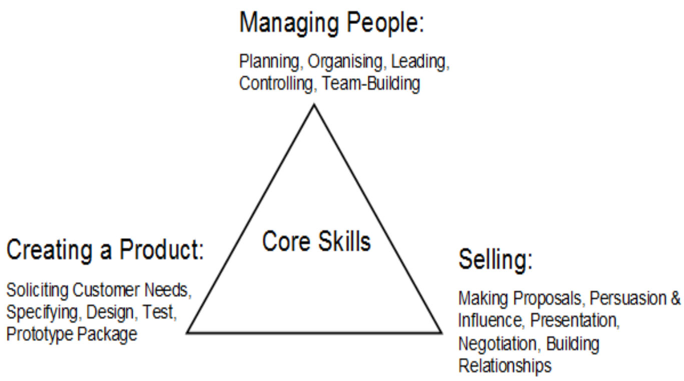
Similarly, engaging business incubation and tech- transfer expertise and leveraging the external networks of campus innovation centres can add value. However, their investor focus can discourage students and faculty if they are unprepared or exposed too early to the harsh world of commercial realities.

Diagram 1: The Cross-Campus Nature of Entrepreneurship Education

Internationally, two delivery models have evolved[21]. The magnet model, commonly used in the US, provides entrepreneurship education to various disciplines from one academic centre. Conversely, the radiant model, as used by Stanford Technology Ventures Programme, facilitates programmatic offerings within the Engineering School. In the absence of a strong centre that can provide entrepreneurship education to different faculty, the challenge resides in developing expertise within faculty and establishing cross-school coordination. Traditional class-room teaching, therefore, in which the 'teacher' knows all is wildly inadequate for the breadth of knowledge and skills required for entrepreneurship. The ACE 'train-the-trainers' programme attempts to address the educator competency gap in this regard by placing a greater emphasis on the educator role as a facilitator in a wider network of expertise.

4.4 SKILLS, VALUES & ATTRIBUTES

A consensus among entrepreneurship educators points to a broader role for entrepreneurship beyond enterprise and start-ups. As a process of opportunity recognition and the acquisition of resources to exploit those opportunities, the skills required can be taught and teaching these skills has academic merit[22]. The difficulty lies in slow diffusion of this message to the wider academic community and the failure to engage entrepreneurs in the teaching process. In addition, the long list of skills identified by industry points to a need for a contextual framework that would 'box' these skills into broad areas of competency. In reality, successful entrepreneurship requires the integration of three broad areas, namely: the ability to sell, the ability to create a product and the ability to manage people (Dia. 2).



While product development is to the fore of most engineering programmes, there is a notable absence in higher education curriculum that teaches people how to sell. Yet, selling is at the heart of entrepreneurship. Entrepreneurs are either selling themselves to investors or other providers of resources for their companies, or they are selling their ideas to potential customers and employees or partners[23]

Diagram 2: The Core Skills of an Entrepreneur.

Similarly, the other core element, i.e. how to attract talented people and manage them collectively to exploit the opportunity, is also difficult to find. Much of traditional curriculum is filled with content, such as accounting and finance, which is irrelevant to a young engineer exploring the world entrepreneurship. Someone can be hired to write a business-plan and financial management is relatively simple; spend less money than you take-in. The difficulty, therefore, lies in the fact that the three core elements are difficult to embed into curriculum whereas everything else in the curriculum, as an entrepreneur, can be delegated to someone else. Skills development, however, is only part of the challenge! Attitudes and values that lead to entrepreneurial behaviours: such as opportunity seeking, initiative and risk taking, seeing thing through, motivation towards an entrepreneurial career, building know-who, emotional self-awareness and achievement orientation, are coaching-intensive and require a more interactive, real-world learning environment[24].

4.5 IT IS NOT WHAT WE TEACH BUT HOW WE TEACH IT?

A common reaction to proposals to embed entrepreneurship into engineering programmes is: *how are we going to fit it in to an already crowded curriculum?* The answer lies in linking the development entrepreneurial attributes with all parts of existing curriculum. Engineering programmes rely on lectures, laboratories and tutorials as the primary tools for delivery. Yet many course modules including professional development, engineering design, business basics, project management and project-work, even abstract subjects such as mathematics, can incorporate enterprising pedagogies to the extent that they can encourage students to use their initiative, be resourceful and opportunistic, take ownership and solve problems in all facets of their life, not just commercial areas. Achieving desired entrepreneurial outcomes represents a major challenge, therefore, in reflecting on how the appropriate learning environment and approaches to teaching can be created[25]. A learning model that emphasises experience, action and reflective processes not only leads to better programme outcomes because students are engaged in authentic learning activities[26] but, as a result of learning in more enterprising ways, students can develop entrepreneurial attributes, almost as a bi-product and irrespective of the curriculum content because they are constantly practised in a wide range of contexts. This, in turn, can increase their entrepreneurial propensity[27]. The development of student entrepreneurial capacities also requires building self-confidence and self-efficacy, which can only be achieved through exposure to entrepreneurial people. Here, campus innovation centres can play a critical role in immersing engineering students in an entrepreneurial environment and allowing them to experience entrepreneurial ways of thinking and behaving and to become responsible for their own actions through personal discovery, performance and experimentation. ACE identified a small number of pedagogical approaches to teaching entrepreneurship in Irish Higher Education, typically limited to the occasional use of entrepreneurs as guest lecturers, industry placement, full or partial modules focused on the business-plan, case-studies, simulation and project work. Yet, there are many more alternative pedagogical tools linked to entrepreneurial behaviour that can be used[28].

4.6 TEAMING

Given that team-work is for enterprise development, ACE specifically looked for examples of teamwork within engineering programmes. In almost all cases, team-work represented only a <u>small fraction</u> of programme learning activities and assessments, underscoring a major discontinuity between graduate skills and industry requirements. Ideally, students should be introduced to the concepts of teamwork and undertake some team-building exercises early in their engineering education. Programmes that can crack the implementation of team-based assignments and assess team-performance as well as individual contributions to teams can better reflect industrial practice. ACE is currently developing engineering programmes in which team-work will form an integral part of learning[29]. Students will form and remain in teams of "virtual companies" that will have to think about products, research ideas and their potential in the marketplace. As peers, students with an aptitude for one subject will be encouraged to mentor others in the team, leading to a wider understanding of the subject matter and to accelerated learning. Students will be expected to run weekly team meetings to discuss latest technology news relevant to their project work, product development progress, assignments and course issues[30]. The intention is that students will better relate theory to practice. There will also be a strong emphasis on exposing students to the professional and industrial environment by giving them the opportunity to pitch to researchers, representatives from industry, potential investors, enterprise development personnel, recruiters and IP experts. The programmes will be supported by the world-wide network of Practice Firms, Europen[31].

4.7 CREATIVITY & INNOVATION

The prevailing attitude towards creativity and innovation within engineering programmes is that it is a soft-skill, a 'nice-to-have' that can be accommodated if there is space in the curriculum. Not surprising, given that engineering is underpinned by logic reasoning and conventions that are the pure and applied sciences. Yet unlocking the right-side of the brain for creative problem solving is as a hard-science in which notable employers such as Google, Hp, 3M and many others invest considerable resources to maintain a competitive edge. Furthermore, many technology start-ups are underpinned by technological innovations borne out of creative thinking. Of the skills cited by students surveyed by ACE, creativity and innovation was number one on their list. While higher education, in the past, has been criticised for paying too little attention to this space[32], there are a growing number of engineering programmatic offerings that are include it formally in the curriculum.

4.8 INTEGRATED PRORGAMMES

To address the low levels of integration of entrepreneurship in engineering ACE has contributed to the development of three new programmes, all of which seek to encourage students to practise entrepreneurial skills in a wide range of contexts (Table 2). Also, several modules have been developed for inclusion in any Level 6/7 engineering programme.

Programme Title	NFQ Level	Owner
Bachelor of Engineering Entrepreneurship	8	Dundalk IT
Master of Science in Technology Entrepreneurship	9	IT Blanchardstown
Bachelor of Science in Engineering Innovation	8	NUI Galway

Table 2: Programmes Integrating Entrepreneurship in Engineering

5 SUMMARY AND CONCLUSIONS

While the contemporary engineer must be able to work in multidisciplinary teams and solve complex problems with a global focus, having an entrepreneurial mindset is now part of that make-up[33]. Although entrepreneurship education may not guarantee graduate entrepreneurs, it can produce graduates with an entrepreneurial skills and attributes. This requires creating an environment of enterprising curriculum, enterprising educators and enterprising learning methods. The pedagogical requirements dictate that development of engineering educator competencies and the cross-disciplinary delivery of the education provision must be addressed. The ACE Initiative has developed a comprehensive set of interventions for pilot to foster the entrepreneurial mindset among engineering students and, in some cases, allow them to pursue technology enterprises. Students and faculty who often begin with little knowledge of how to start a technology company are provided with a wide range of substantial opportunities to learn and develop entrepreneurial skills. Based on international experience[34], we are confident that our holistic approach to campus entrepreneurship will create engineering graduates with the entrepreneurial skills to grow viable ventures that will impact their careers and destinies. However, given the inherent time-lag between these interventions and their effects, only time will tell how the graduate journey towards entrepreneurship will unfold.

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Challenges in Providing Practical Labs Online to Distance Learning Students

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Abstract: Delivery of engineering courses online is a growing area of demand and one which has a key role to play in Ireland's economic development. The National Skills Strategy outlines the requirements to realise the government's vision of a new knowledge economy which can compete effectively in the global market place. This states the need to up-skill 170,000 individuals within the workforce to third level education by 2020. In this context, the ability to fit an on-line course around full-time work is of huge benefit to both students and their employers.
The Institute of Technology, Sligo is Irelands leading online learning provider. Since 2001 the Institute has delivered "live" classes to distance learning students over the Internet on a range of engineering courses from Ordinary Degree to Masters level. A major challenge faced in delivering online courses in engineering is the difficulty in linking theory with real world problems through practical application. IT Sligo are aiming to address this issue through a collaborative EU funded project, "Knowledge and Innovation Transfer in Engineering" (KITE). In this paper we describe the technology we use for facilitation of online practical classes, and discuss the student and teacher experiences during the initial stage of the KITE Project.

Keywords; distance learning, on-line, remote labs.

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1. INTRODUCTION

1.1 Demand for on-line learning in engineering

Due to advances in communication technology, engineering education is experiencing widespread changes in the modes of delivery, with educators taking advantage of the internet in enhancing the teaching and learning experience. Online tools such as Learning Management Systems (e.g. Moodle, BlackBoard) are commonplace in Further and Higher Education for organising and disseminating class resources; communicating with students; running on-line assessments and encouraging student collaboration (discussion forums etc.). The major benefits however are in the realm of distance learning – an area of education which is currently seeing unprecedented growth. For example, as illustrated in Figure 1, in the USA enrolments in online courses grew by an average of 20% per year from 2002 to 2007, far exceeding the average 1.5% growth per year in the overall Higher Education student population (Babson Survey Research Group, 2009).

The major driver for expansion in on-line learning is in adult education, where individuals are looking to continue their education to 'up-skill' or retrain. The flexibility associated with an online program is ideal for those in work who may also have to balance family and other commitments. The recent economic situation has further accelerated demand for flexible, online learning with employees, corporations and government recognising that skill development in high tech and knowledge based areas is crucial for recovery. The Irish Government have committed to up-skilling of 170,000 workers to third level by 2020 at an estimated total cost of €4billion (Department of Enterprise, Trade and Employment, 2007). Clearly, online delivery represents the ideal medium for achievement of this target.

1.2 Challenges in delivering engineering education on-line

Despite the advantages of online delivery, there remain many issues in achieving a high quality educational experience for students and lecturers, particularly in subjects with a significant practical component such as engineering. Critics argue that online delivery does not offer the same intellectual experience as face-to-face classes; that it leads to isolation of students (and hence retention issues); and faculty are divided over whether online learning provides the same learning outcomes as a traditional course. However, negative views of online learning are generally held in institutions which do not offer online courses; for those actually engaged in delivery of complete courses online, opinion is often reversed, with more believing that learning outcomes online are at least equivalent to if not better than 'face-to-face'(Babson Survey Research Group, 2009). Clearly, both teaching practice and the technology used in online courses have an important role in challenging these critical perceptions.

At IT Sligo, online degree programs in engineering have been running since 2000, with the number of students growing from less than ten in the first year to over 500 in the current academic year. The online courses combine a Learning Management System (Moodle), with live online lectures and four on-site days per year for carrying out practical work. The live lectures are a key component of the learning experience, whereby remote students can interact throughout the class by asking questions and participating in live discussion. Typically, online students are up-skilling or specialising for their current employer (i.e. currently working as technicians, operators or engineers) and have several years practical work experience. The current courses are highly regarded by both students and employers, but it has also been recognised that there are areas where the courses could be improved, particularly in covering the practical content of the course. The number of on-site days is limited to achieve a balance between covering the required content while limiting the time off work and travel required by the students. This generally means that the days are extremely intensive, and students can struggle to take everything in. Timing of the practical exercises can be quite removed from the teaching of the theory (also a common problem with traditional face-to-face courses). With four intensive days over the year, the opportunities for student collaboration are more limited than in conventional courses. Also, the need to be on-site to cover practical content or for access to software not freely available to the student (e.g. Matlab, SolidWorks etc.) has to date limited the capability to offer some courses online – e.g. Mechanical Engineering with its large component of teaching in CAD and FEA etc.

A new project at IT Sligo aims to address these challenges in online delivery to further enhance the quality and scope of online teaching available. The EU funded Knowledge and Innovation Transfer in Engineering (KITE) project involves a partnership with Northern Regional College, Northern Ireland and Ayr College in Scotland. The aim of the project from the IT Sligo perspective is to facilitate delivery of practical content of courses online to develop a richer learning experience for students, with more interactive, practical, real-world application throughout the course and better use of the on-site time. Aims of the project include: remote access to laboratory hardware rigs for experimentation; interactive online training in computer-based applications; and on-demand access for students in their own time. Through this process we aim to enhance the opportunities for student collaboration, and peer-to-peer learning and support. In the following sections we describe the technology available for facilitation of online practical classes, and discuss the student and teacher experiences during the initial stage of the KITE Project. As outlined below, progress to date includes delivery of CAD teaching online and the initial development of online laboratory exercises in Automation technology and Control Systems courses.

2. TECHNOLOGY FOR ONLINE PRACTICAL CLASSES

2.1 Review of remote labs and remote learning technology

The concept of online labs is not new and many institutions have to date implemented remote lab programmes in engineering. Initial attempts involved internet accessible simulations (e.g. Michau et al., 2001), which while providing many advantages such as visual feedback to the student and robust operation, simulations often ignore real world nonlinearities and complexities and do not provide the experience of actually operating the equipment. Interaction with hardware via the internet is a more recent development afforded by the development of java applets which allow access through a standard web browser. Such systems involve a physical rig equipped with sensors and actuators to monitor and manipulate the system via a PC. An extensive review of virtual and remote labs has been conducted by Bencomo (2004). The advantages of remote labs include flexibility in the availability and access to laboratory equipment and the sharing of expensive resources between different institutions (Harward et al., 2004, Lowe et al., 2009). However, there are a number of disadvantages associated with existing remote lab programmes, including the time and cost in developing bespoke software for web access and in general the limited nature of the exercises available. With lack of direct supervision and interaction with an instructor, most exercises are strictly controlled to ensure safe and reliable operation of equipment. Furthermore, some labs require integration of different software applications and systems which can be difficult to achieve in a web application. This limits the extent to which a student can engage with and experiment with the equipment and in many cases may deem certain exercises to be unsuitable for online use.

Introducing a collaborative element to remote labs has recently become topical, with many providers recognising and aiming to address some of these shortcomings. A number of projects have begun looking at integration of collaboration tools such as instant messaging or audio between students and/or an instructor (e.g. Emani and Helander, 2008; Lowe et al., 2009; Machotka et. al 2010). These projects again involve intensive investment in development of bespoke software and while promising have not been fully implemented and tested to date. The recent development of application sharing and 'remote desktop' software offers an alternative route to delivery of online labs which has many advantages. Remote access to lab equipment can thus be achieved without considerable investment in software infrastructure; a number of different applications can be easily hosted and run alongside each other and collaboration can be facilitated by allowing multiple users access the same PC via desktop or application sharing software. Opportunities also exist to allow remote students to access institution PCs for live hands-on class training on any computer based application. However, there are to date few reports in the literature of colleges and universities making use of such facilities either for remote labs or for live 'hands-on' classes. Jernigan et al (2009) recently reported use of NetMeeting® for a remote, interactive control systems experiment at North Carolina State University. This allowed an instructor to communicate with small groups of students via VoIP audio, while sharing the desktop hosting the experimental rig - which the students where then able to control remotely. This resulted in positive student feedback but had the disadvantage that students couldn't also access the rig independently for preparatory or follow-up work. Machotka et al. (2010) reported a trial of remote lab collaboration using Centra® software alongside the NetLab web-based remote lab architecture. NetLab provides for independent remote access to experimental rigs, while Centra facilitated audio communication between students sharing the same NetLab resource. This system obviously relied on the NetLab infrastructure which has been developed at the University of South Australia.

In this work, we report the use of commercially available software for deployment of remote labs both for on-demand, individual access and for use in a collaborative, classroom environment. We examine some of the benefits and issues around facilitating live 'hands-on' instructor-supported learning on computer based applications and show how remote labs can be easily developed for both on-demand access and in-class collaborative working. While, the developments in technology mean these systems will have wide appeal, there is to date little in the literature to address these themes.

2.2. Chosen strategy

For effective teaching of practical classes online, we felt a mix of on-demand remote access and interactive live classes was needed. Teaching of software or any computer-based application online is now achievable at relatively low cost using virtual classroom software. An important constraint is that in many cases the student does not have access to the application on their own PC outside the Institution. For this reason, it is important to give the students access to PCs within the college. We could only find one commercially available software package, Webex Training Center®, which would enable a number of remote computers to be made available to students in a virtual classroom environment – meaning that each student could take control of an individually allocated PC while maintaining contact with an instructor.

It is also important to augment the live classes with the facility for students to access resources (software or hardware rigs) on-demand in their own time. While remote desktop applications are widely available it is important that access to specific computing resources be controlled such that only registered students on a specific module be given access; that access is scheduled around times the resources are available; and that the length of time any one student can spend on a resource in one session is limited so that it can be freed up for other users. Conveniently the Webex Training Center includes this management of PC resources as part of its service. Other brokering/scheduling solutions for PC resources are available (e.g. HP Session Allocation Manager) but these do not offer the classroom facility.

3. ONLINE CAD TEACHING

3.1 How a class works

CAD teaching is delivered through a live online tutorial using the 'Hands-on-Lab' feature in Webex Training Center. Two-way VoIP enables communication between the lecturer and students. Students have the ability to control their own microphone mute or unmute state. Also the lecturer is able to mute students as required. As VoIP quality degrades with a large number of open VoIP channels, students are encouraged to mute their own microphones until they have a question or point to discuss.

The format of the class generally involves a CAD demonstration by the lecturer hosted on his own PC with the screen shared to the class. This is followed by a 'hands-on' session where the students are each given access to their own PC in the CAD lab to work on the software themselves. The lecturer can from his own PC 'hop' onto any of the student machines to view their progress or take control of the mouse to assist the student. When the lecturer joins a student PC there is the option to open a private VoIP channel so that the discussion is not heard by the rest of the class. In practice, the lecturer finds it easier to run the class from the CAD lab and use a radio headset while walking around the lab to view the student progress on each monitor.

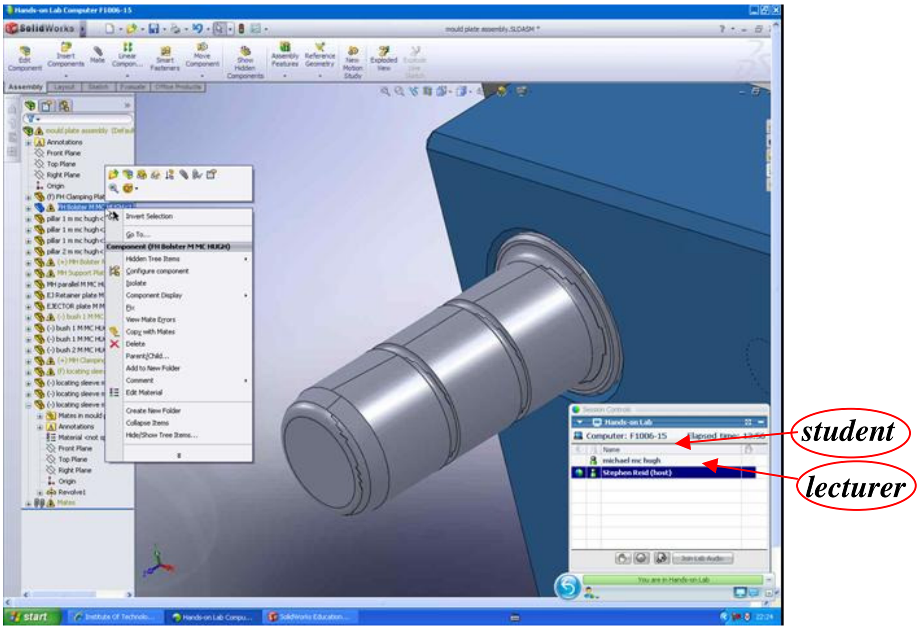


Figure 2 Screenshot of lecturer joining a student on a remote PC (based in IT Sligo CAD lab) to provide assistance in the live CAD class

3.2 Student and Lecturer feedback

The class of 15 students were polled to get some feedback on their experiences of the pilot online CAD class. When students were asked if they would recommend CAD training delivered in this way the answer was a unanimous yes. Students were asked whether they would still find a live class beneficial if they were able to watch video demonstrations of the course tasks, 93% of the class said that they would. The main reason for wanting a live class was split between those who wanted to get individual help with problems and issues, and those who primarily valued the experience of engaging with the rest of the class during the live tutorial. Despite these positive aspects, some students did report technical problems with the class. 27% reported some issues with sound quality – although in half the cases this was due to feedback caused by students forgetting to mute themselves. 20% reported occasional issues with their internet connection crashing during the class. Broadcasting a remote desktop in a live lecture where VoIP and other information must also be transmitted is bandwidth intensive, particularly with intensive graphics software and does demand a good quality broadband connection. We've found typically users with around 1Mbps upload speed have a perfectly acceptable experience; however communication quality can vary significantly with time depending on the service provider.

From the lecturer point of view the class worked very well, although there is a steep learning curve in running such a highly interactive class online while coping with teething technical problems such as getting students set-up correctly, becoming familiar with the best way of using the technology etc. Developing training for both students and lecturers in tools and techniques for a successful, problem free class is an important future objective.

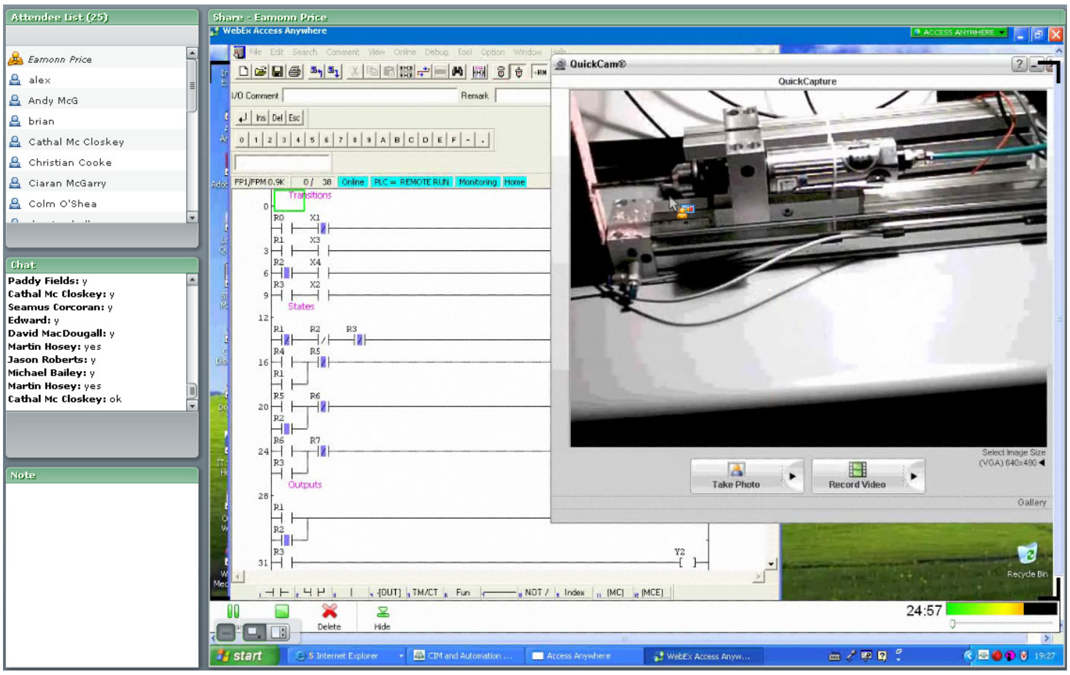
4. ONLINE LAB EXERCISES

4.1 Automation Technology

As part of the Mechatronics degree programme at IT Sligo, students are required to study an Automation Technology module, a significant component of which comprises the design, build and programming of PLC systems. At present online teaching involves a live lecture covering theory, and four on-site labs a year. The onsite practical sessions are extremely intense as students have to comprehend the nature of the system under design, the programming of the code and the physical wiring for a number of different exercises in a short space time. The background knowledge of the students is extremely mixed, with some students having no prior experience of PLCs, while others work with them as part of their job on a regular basis. This makes it extremely difficult to manage the class and ensure the expectations of all are met. The availability of rigs which can be accessed online and which the student can observe via a video camera for instant feedback would be an ideal solution to these problems – freeing up the onsite time to focus on physical aspects of building and wiring systems.

To date we have implemented a number of rigs for demonstration during a live class. Here, during the live lecture, the instructor connects to a remote PC in the lab which is interfaced with a PLC system. The screen of the remote computer is then shared with the entire class. The instructor can demonstrate programming the PLC, downloading the code and observing the behaviour of the system in real-time. Figure 3 shows the live demonstration of PLC executing a rapid approach drilling system. In this application the video feedback was obtained using a webcam which was displayed on the screen of the remote computer. Although this worked well when one user was connected to the remote PC, the heavy use of bandwidth in the live class meant that the picture observed by the students was somewhat jerky. We are currently looking at ways to improve this; the use of an IP camera to stream video to a website which can be run on the local rather than the remote computer appears to offer the most promising results.

Figure 3. Screen shot of PLC lab demonstration in live lecture



We are currently in the process of designing, building and managing a range of rigs for design and testing of different types of PLC programs for remote access by the students in their own time. Of 24 Mechatronics students surveyed, 100% felt that this would be 'Helpful' or 'Very Helpful' in improving their understanding in this topic. A future development is to look at running a live online 'tutorial' class where students can be given access to a suite of rigs in a PLC lab, either in small groups or as individuals, with live feedback from a lecturer who can observe their progress in the classroom.

4.2 Control Systems

For Control Systems teaching, two rigs have been developed to enable a range of different exercises supporting all main aspects of the curriculum at Levels 7 and 8 (BEng and BEng(Hons)). One is a process control rig facilitating a range of identification, PID control and introductory digital control experiments on level, pressure and temperature control loops. The second is an inverted pendulum rig, presenting a classic problem in control engineering of a non-linear and unstable system, it facilitates teaching of more advanced concepts including state-space modelling and control strategies. LabVIEW software is being utilised to implement simple, specific exercises for straight forward aspects of the course – creating a range of easy to understand mini-labs for students to access on demand in their own time to support application of the theory as they learn it. For more complex work, such as the design and testing of digital controllers developed by the students themselves, this will form a larger student project where the online testing is supervised by an instructor in the classroom environment. This is to ensure that the controller will not cause damage to the equipment and also to support the learning of the students with guidance and feedback during the experiment. This model balances the advantages of the flexibility of carrying out minilabs at any time which suits the student, as well as offering opportunities for the students to collaborate and learn from each other on the more complex exercises.

5. CONCLUSIONS AND FUTURE WORK

We have proposed an architecture for facilitating online practical classes in engineering based on commercially available software. Initial steps have been made in implementing a range of laboratory exercises to reinforce practical application of theory throughout an online course, in autonomous, cooperative and collaborative learning modes. We have successfully delivered online teaching of a CAD module through a mix of interactive live tutorial classes and on demand access to CAD software for remote students. This pilot study has highlighted some of the benefits and issues for online learners and their lecturers in exploiting recent developments in web technology for engineering education. The technology used in facilitating remote access has the advantage in needing little or no computer programming knowledge, and has the flexibility to be used by students working on their own or in collaborative sessions with a live tutor. We are currently evaluating alternative technologies to address issues including improving the broadcast of dynamic video and dealing with weak internet connections. Arguably the most important developments will be in developing the pedagogy and teaching skills and to maximise learning potential in the interactive, ‘hands-on’ environment.

ACKNOWLEDGEMENTS

Funding for this work has been provided by the ‘Knowledge and Innovation Transfer in Engineering’ (KITE) project supported by the EU INTERREG IVA programme managed by the Special EU Programmes Body.

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REFLECTIONS ON TRIALLING TWO TEACHING STRATEGIES FOR SUSTAINABILITY MANAGEMENT EDUCATION IN AN UNDERGRADUATE ENGINEERING MODULE

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Abstract: This paper focuses on the effects of trialling two teaching strategies for sustainability management education in an undergraduate engineering module. The first strategy involved delivering a lecture using the TEAM EFFORT formula on the Work Practices & Management module within the School of the Built Environment (SCOBE) at the University of Ulster, Jordanstown (UUJ). This TEAM EFFORT formula is part of a teaching strategy used to deliver and evaluate the required multi-disciplinary approach to sustainability within the built environment. The TEAM EFFORT formula consists of: TE = Team Effort; AM = Appropriate Management; EF = Evaluation Framework; FO = Focused Outlook; and RT = Risk Translation.

The second strategy involved a TEAM EFFORT approach within the same module, in the form of a management simulation assessment referred to as "The Consultancy" which also focused on sustainability. Groups for The Consultancy were multi-disciplinary drawn from programmes within SCOBE. Over a 5-week period, the groups were given tasks to solve by choosing from multiple choice answers. The tasks involved knowledge and understanding of several factors including environmental, economic, social, safety and resource management. The best performing group overall, in terms of selection and justification of its answers, was judged by a chosen industrialist.

The results of formative student assessments for both strategies using this TEAM EFFORT approach showed that the students' awareness of the linkages across the pillars of sustainability had improved. However, this was not as evident in the summative assessments for this module at the end of the semester. These results highlight the short-term effectiveness of these approaches to teaching and student learning and the need for further pedagogy research to achieve deeper learning and improved sustainability management and employability skills for graduates.

Keywords: Assessment, Management, Sustainability, Teaching Strategies, Team Effort.

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1. INTRODUCTION

1.1 Sustainability Management

The background to this paper relates to the need to apply the principles of sustainability to the management of the infrastructure within the built environment. However, there are many problems associated with basic infrastructure in the UK and Ireland.

In 2006, almost 5,000 homes in England and Wales were still experiencing problems related to flooding despite there being a drought that summer (Goring, 2007). Goring also states that 3,500 million litres of water were lost every day during that period due to leaking watermains. The cost of flood damage from summer flooding in the UK in 2007 has been estimated at a cost of £3 billion with approximately 3,600 Yorkshire businesses and 500,000 homes affected; approximately 145,000 people had no water supply when the Mythe water treatment plant (WTP) in Gloucestershire flooded (Oliver, 2007).

In the past decade, people in UK and Ireland have been exposed to the virus cryptosporidium in their drinking water supplies (Engineers Ireland, 2007). Increased precipitation has also led to flooding episodes on the island of Ireland, the most notable being Cork City in 2009 (Independent, 2009). In Ireland, significant increases in winter precipitation levels have been detected (EPA, 2002).

The myriad of problems which face infrastructure performance require solutions that are based on a collaborative approach. In this context, civil engineering students need to develop problem-solving skills by gaining knowledge through learning. A basic concept of learning is that in order for students to learn at a higher level, they must possess a good understanding of the fundamentals of their subject area. Many programmes in higher education are designed so that students build incrementally on their existing level of knowledge; thereby, students need to ensure they have a good grasp of the prerequisites to help facilitate a smooth transition to the next level. In relation to sustainability, the aspiration at University of Ulster at Jordanstown (UUJ) is to thread sustainability through all modules within SCOBE. One particular module, Work Practices & Management provides two explicit sections in terms of sustainability management:

1. The ‘TEAM EFFORT Formula’ which clearly shows that a collaborative approach is required to achieve sustainable development.
2. ‘The Consultancy’ which splits the class into multi-disciplinary teams that are given weekly tasks that involve the sustainability management of a construction project.

This approach links to other modules within SCOBE as environmental, economic and safety issues are considered.

1.2 Teaching Strategies

Learning is… “*about change: the change brought about by developing a new skill, understanding something new, changing an attitude…is a relatively permanent change, usually brought about intentionally and purposefully*” (Reece & Walker, 2003, p.59).

However, not everyone learns in the same way, which is an important consideration for lecturers in education (Fry *et al.*, 2003). Indeed, it is hypothesised that the approach to learning which a student employs is both personal and situational (Ramsden, 1988). It is recommended that lecturers should consider how to bring about change or transformation to the pre-existing knowledge of their learners (Mezirow, 1991).

Different approaches to learning exist (Ramsden, 2003) and approaches to and successes in learning are linked to the motivation of the students to learn (Reece & Walker, 2003). This motivation relates to whether the students are determined by outcomes rather than their understanding of the subject (Reece & Walker, 2003). The works of Marton (1974), Entwistle

(1986), Ramsden (1988) and Biggs (1987) have conducted numerous research studies into the area of learning approaches. Their investigations have led to three main approaches – the Surface Approach; the Deep Approach and the Strategic Approach, which can be briefly explained as follows.

The main characteristics of the surface and deep approaches to learning are contained in the work of Ramsden (2003). In simple terms, *surface* learning is about quantity without quality; deep learning is about quantity and quality (Biggs, 1989). From a lecturing perspective, this surface approach to learning would not be conducive to learning as many of the modules on courses require underpinning knowledge of previous modules. Furthermore, this has further implications as graduates progress into employment in industry. A deep learner can become actively involved in the course and will carefully examine the logic behind the entirety of the course content. Meanwhile, the *deep* approach to learning is the '*intention to understand*' (Ramsden, 2003, p.47). A student who employs a deep approach to learning is utilising previous knowledge of the subject and/or any experience relating to the subject area. This is a more desirable approach as students actually develop an interest in their subject which allows them a greater understanding of the topic, and the ability to integrate the material.

Thirdly, the *strategic* approach typifies students who "*adapt their learning style to meet the needs of the task*" (Fry *et al*., 2003, p.440). A student who engages a strategic approach, also known as the Achieving Approach to learning, is doing so in order to achieve the highest possible marks for their own sake but not necessarily to signify a high level of learning. The strategic approach can use a combination of the surface and deep approaches to learning. A student who primarily uses a deep approach to learning may adopt some form of the techniques of a surface learner in order to obtain a high grade. Thus, the deep approach is not a permanent approach of the student as achievement is mainly associated with the exam or assignment grade, as articulated in the summative assessment

Although a number of learning styles have been described, it is not appropriate to label students into specific categories. Most learners have a primary surface learning style but this can depend on the subject and situation. Lectures must be designed so that everyone on the programme develops and adapts their specific level of learning. However, Felder & Silverman (1988) concluded that the preferred teaching style of most engineering faculties was not meeting the best learning style of engineering students. Different students have their own individual methods of remembering information, showing creativity and demonstrating understanding. These methods can include mind mapping and the use of acronyms.

Lecturers continue to aim to facilitate students' learning, especially in the creation of long-term memory (Herbert & Burt, 2004). Studies have highlighted the advantages of mind mapping as a technique to enhance learning (Mento *et al.*, 1999; Buzan & Buzan, 1995; Buzan, 2002; Buzan, 2005). Stalder (2005) showed that the use of acronyms consistently predicted higher performance in an acronym related exam, and helpful in increasing student motivation to study. However, others have questioned their effectiveness (Carlson *et al.*, 1981; Carney *et al.*, 1994).

2. METHODOLOGY

2.1 TEAM EFFORT Formula

The TEAM EFFORT formula is a teaching tool using an acronym which is presented to students as follows: TE (team effort) = AM (appropriate management) + EF (evaluation framework) + FO (focused outlook) + RT (risk translation). Part of the lecture PowerPoint presentation entitled "*How can Work Practices & Management influence the direction and focus of sustainability?*" is shown on *Figures 1*, *2* and *3*. The formula was devised as a study aid to assist students in applying the principles of sustainability by using a team effort approach. Eighty undergraduate students in total attended the lecture. Each of the four criteria, which form the TEAM EFFORT formula, has specific sub-headings which are expanded upon during the lecture. This helps the students understand what *is* required to provide sustainable solutions.

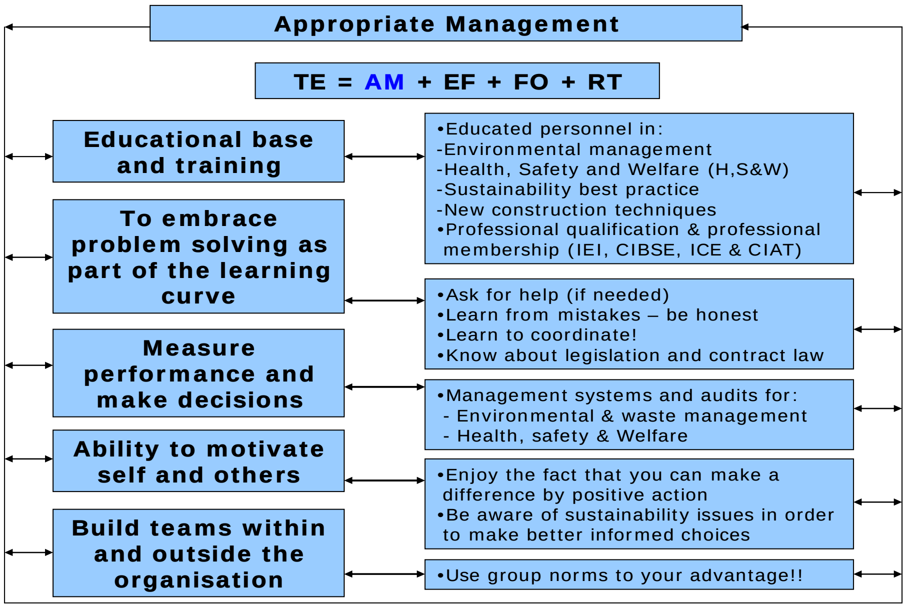

Figure 1 Appropriate Management

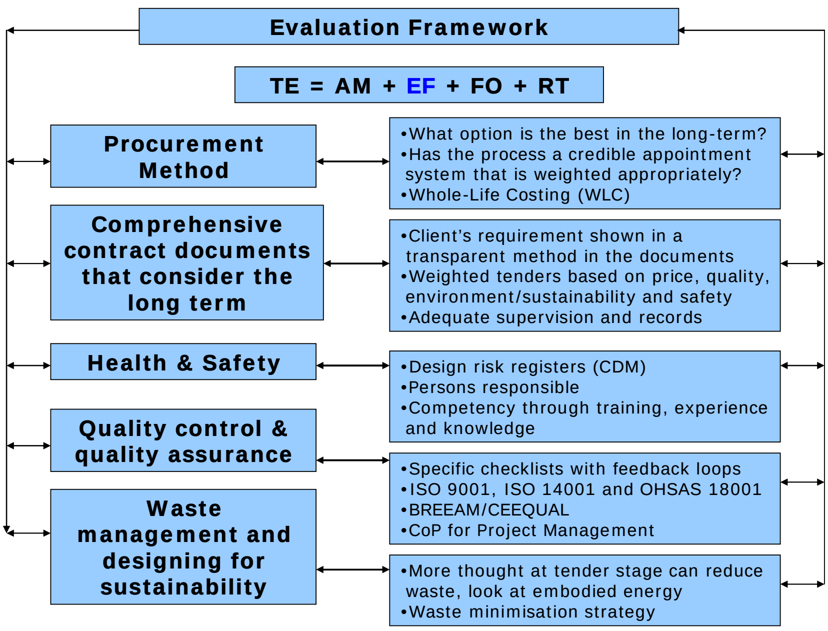

Figure 2 Evaluation Framework

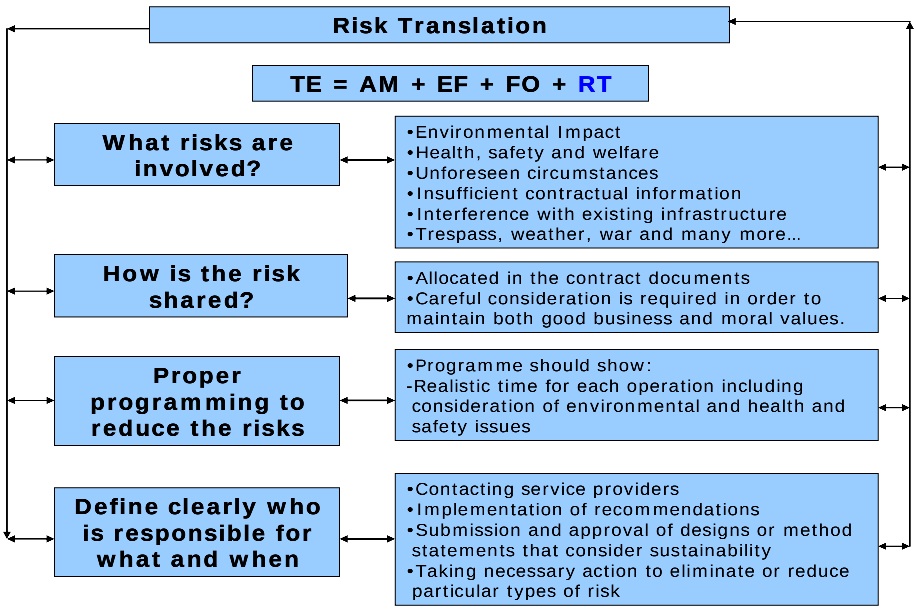

Figure 3 Risk Translation

2.2 The Consultancy

The Consultancy requires the class to be split up into approximately ten groups of eight students each. The students in these multi-disciplinary groups are from programmes within SCOBE. The Consultancy takes into account sustainability in construction as opposed to a complete focus on tendering/cash flow. Each group is assigned a specific role; for example, SCOBE consultant, building services consultant, architectural consultant. Over a 5-week period, the groups are given tasks to solve in terms of choosing the most appropriate answer to a given question from a choice of three answers.

The project, which was assigned to the class in the 2009-2010 academic year, involved the construction of an access bridge over an existing river. Part of the site was on a flood plain and the site was adjacent to a wildlife sanctuary.

Each group had to submit its answer by a specified deadline on each consecutive week. The best performing group overall, in terms of selection and justification of their answer, was judged by a chosen independent industrialist. Each student in the class used their role within the simulation to submit an individual report which conveyed their experiences from the simulation. The individual report accounts for half of the coursework mark in the module.

3. RESULTS

3.1 TEAM EFFORT Formula

The 2009-2010 Work Practices & Management examination had a specific question that related to the TEAM EFFORT formula. The average results for this question were lower than similar qualitative questions within the exam paper. It appears that this was due to the students providing a large amount of theoretical information on teams/groups as opposed to concentration on the formulated approach to sustainability management delivered in the specific lecture. *Figure 4* illustrates that the majority of students only managed to achieve approximately half the marks for this question, with a median score of 55%. Although they effectively recalled the theory on team work, their answers did not necessarily link the TEAM EFFORT formula to sustainability. Thus, the results do not concur with all the theoretical information on the use of acronyms in teaching, and indicated that there was only surface learning achieved, despite the attempt to develop deep learning. It is also worth noting that this sustainability question was the second lowest performing question out of a total of seven questions in the exam paper.

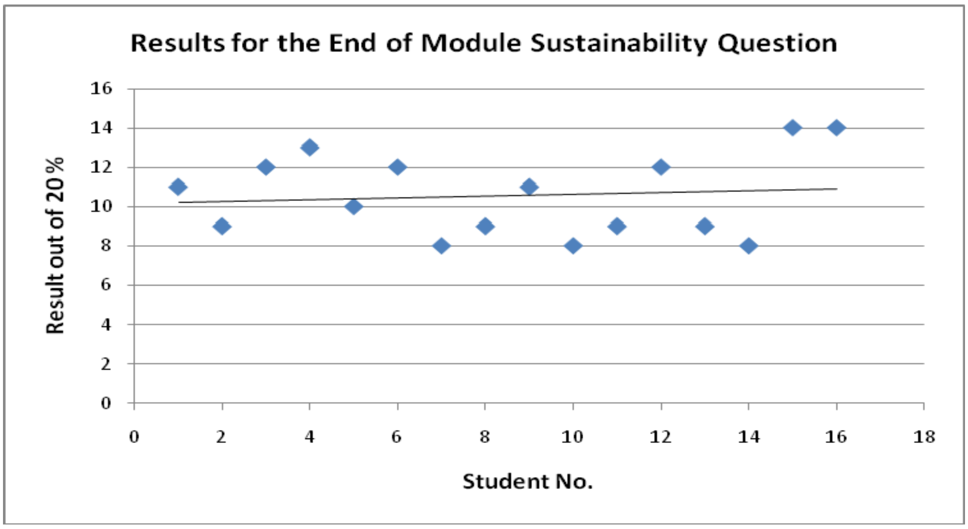

Figure 4 Results for the End of Module Sustainability Question

Considering these results, it is proposed that the TEAM EFFORT formula lecture material will be delivered as a six-hour workshop in the 2010-11 academic year, to embrace both surface and deep learning. This is not merely an attempt to improve formative or summative assessment but to improve sustainability management for life. Further development of the sustainability aspect of the module may include a specific discussion board for the TEAM EFFORT formula and the inclusion of an online quiz. These would be particularly useful forms of assessing student performance and engagement.

3.2 The Consultancy

Since the introduction of implicit consideration of matters relating to sustainability within the management simulation consultancy in 2009, the average individual assignment results for "The Consultancy" dropped from 67.7% (±9.91) in 2008-09 to 62.38% (±6.80) in 2009-10, (see *Figure 5*).

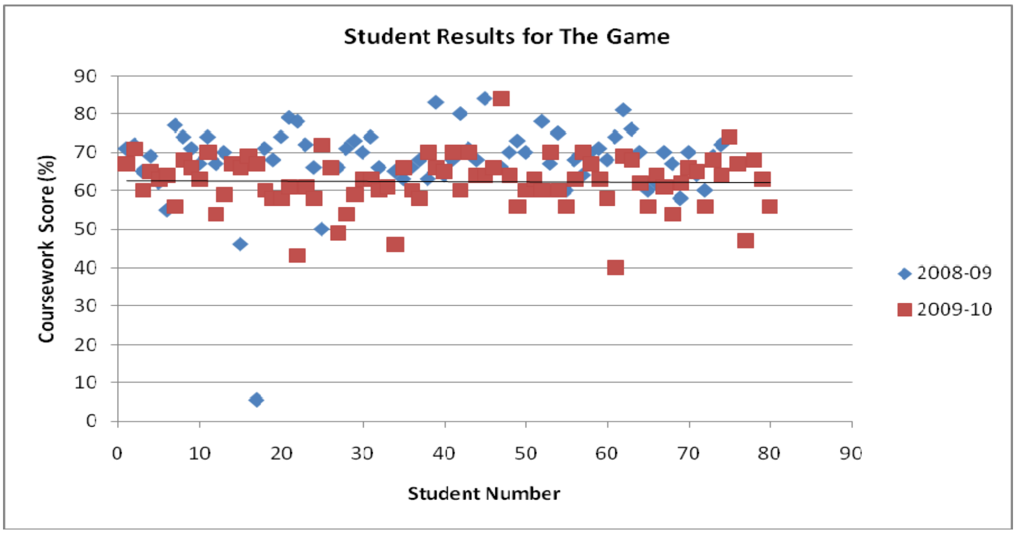

Figure 5 Student Results for The Consultancy

There was no distinction shown across the three built environment disciplines, in this reduced summative performance. This also suggested that the attempt to integrate the more complex aspects of sustainability was not fully achieved.

4. CONCLUSION

The collaborative approach given in the teaching of sustainability management in the Work Practices & Management module at UUJ is in line with what is being called for by leading institutions. Mr. John Power (Director General, Engineers Ireland) has proposed that the relevant bodies collaborate with Engineers Ireland to facilitate greater coordination for flood management (Engineers Ireland, 2010); similarly, sustainable development is a core requirement of the Engineering Council in higher education programmes which provide under-pinning knowledge for potential chartered engineers (EC UK, 2007). Whilst Power’s comments are set in the context of coping with floods, this broad and deep approach is required for all aspects of our infrastructure, and to satisfy the broader sustainability requirement.

The results of the summative assessment relating to the introduction of explicit sustainable development management themes into the Work Practices & Management module showed that a number of students found it difficult to apply the theory to cross disciplinary understanding and analysis needed within sustainability management; however, a good knowledge of team/group theory was demonstrated. Graduates must be equipped with the transferable and essential skills relating to decision-making, problem-solving, managing people, working as a team and communicating outputs whilst instilling in them the sustainability ethos. The research undertaken within the universities will help governments and consulting engineers to make the right decisions. This is highlighted by the Irish Academy of Engineers and Engineers Ireland in the 2010 report on *Infrastructure for an Island Population of 8 million*.

> “*The complementary nature of the major research capabilities should be supported by all-island grant and incentive mechanisms, particularly those facilitating the trend towards increased enterprise-academia collaboration*”.
>
> Irish Academy of Engineers and Engineers Ireland, 2010, p.57.

It is evident that SCOBE graduates from UUJ who progress to industry rather than postgraduate study still possess the foundations and skills in being able to undertake research that relates to sustainable development and sustainable management. However it is also evident that there needs to be ongoing pedagogical research and experimentation to achieve deep learning for graduates in order that they naturally embrace the holistic and integrating thinking of sustainable development and sustainability management. Therefore, module delivery is of vital significance for the future, so that the Work Practices & Management module fully assimilates the dynamics of the challenges of employment and multi-disciplinary and professional thinking, and that graduates become sustainability managers irrespective of their discipline. In summary, this study highlights the short-term effectiveness of two approaches to teaching and learning and the need for further pedagogy research to achieve deeper learning and improved sustainability management and employability skills for graduates.

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TEACHING A COURSE "TECHNOLOGY AND ENERGY AROUND YOU"

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Abstract: An emerging introductory interdisciplinary course, in which students are introduced to the technology and energy needs they experience everyday, is described.

The university community as a small city has been considered for study by students. The cooperation between various university constituents allows students direct access to the facilities to see some of their principles implemented into action facilitating the next step in the process, analyzing the resulting improvements. This cooperative effort creates a mutually beneficial situation where students gain access to the data and knowledge of the facilities personnel; while the facilities personnel gain access to the results, of the course studies, as possible directions for future action in sustainable efforts.

The emerging course focuses on introducing students to the technology and energy use of the university. This includes the space and resource needs of the community through the resource consumption modalities, particularly air conditioning, lighting, fresh air, potable water, non-potable water and safety requirements at all levels in the hierarchical university system. Physico-chemical and biological principles of utilities are explained from the very beginning.

Keywords; symposium, engineering education, transformation, society, international, sustainability.

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1. MOTIVATION

Sustainable design and development is not a single topic to be covered as a section in a single lecture course. It is a cross disciplinary mindset that must be developed over a series of courses reinforcing the ideas of lowering the impact of designs from cradle to grave. (Azapagic, 2009; Ray, 2009) Courses are emerging that immerse students in sustainable use and design. The concepts of sustainability are being introduced in these courses through lectures into energy production and consumption and followed by contrived case studies to demonstrate teachable points. (Evans, 2009; Azapagic, 2009) The course being developed uses this framework as a starting point, but rather than contrive cases or use historic cases this course reaches out to the facilities staff at the host institution to develop cases based on current and future efforts that are local to the institution. By developing cases in this manor the students have first hand access to the data sources and can participate in the process from identification through final design installation. Through this interaction of students with facilities personnel on local case studies of energy usage students are introduced to the technology and energy needs they experience every day.

2. PEDAGOGICAL FRAMEWORK

Students come to campus generally never having paid a utility bill, purchased an appliance, or priced a structure repair/remodel. They generally have no experience in where energy and resources are consumed, saved, and wasted. This course begins by opening the student's minds to where energy and resources come from, how they arrive at the university, what they are used for by the university, what by-products are generated by their consumption, and what is done with these by-products. After introducing the resource flow within the university the course focuses on the interaction of these local resource flows within the global resource markets. The course spends some time discussing the effects in disruptions in the interactions between the local and global resource flows and forces students to develop plans for lifestyle sustainment.
Using local resource flow has an advantage in that information and cases can be obtained from within the university. Working closely with the facilities manager we have been able to obtain information on resource usage, broken down by hour in some cases, to tour the facilities spaces in the building, and to have access to the support personnel that maintain the systems. Students benefit by having a direct line of contact to the people that know the answers when questions come up.

The benefit of cooperating with local facilities managers to develop discussion topics and ideas is not a one way aid. The facilities managers have the opportunity to pose problems they are currently tasked with solving to an entire class of engineering students. This leads to a number of different approaches being investigated without requiring time and effort from the facilities department.

This course is structured as a standard lecture course. It will have three 50 minute sessions scheduled each week for 15 weeks. These lectures will be replaced with discussion sessions with the facilities department, field trips to in place infrastructure and project work sessions as necessary throughout the semester.

3. RESOURCES AND TECHNOLOGY WITHIN THE LOCAL UNIVERSITY

Most universities are setup much the same as a small city. They have areas divided into residential, office space, medical, recreational, food service, and retail. Each of these spaces has a different set of resource needs and operational parameters. When generating a sustainable plan of operation for such a diverse collection of spaces there is no overriding norm. The resource utilization, access, and self sustainability all differ widely.

Saint Louis University is not unlike other medium sized universities. It has 128 buildings on 234 acres of land. These buildings have 5.2 million square feet of space divided amongst: Academic, Office, Residential, Retail, Medical, Athletic, Museums, and Theatres. There is an additional 1.5 million square feet of parking. This space is home to 12,000 students and a workforce of 5600 employees. Just like any city these spaces have varying hours of operation and function.
The main focus of this course is not on innovation but on making better use of available technology and resources. This course is targeted at early undergraduates to expose them to sources, transportation, storage, usage and by-product production of resources. The students will be exposed to current and emerging techniques and technology that can be used to stabilize the current system of resource delivery and usage. They will also develop ideas to become more self sufficient in the case of resource disruption.

This course will be project and case based with most of the case material being drawn from interactions with the facilities department of the university. Drawing material from the local facilities department gives the faculty and students direct access to the material being studied. Tours of the facilities being studied can be taken, material can be obtained about the facilities with a phone call, and any innovations developed during the class can be directly implemented under the observation of the students.

3.1 Principles of resource creation, distribution and consumption

This lesson will concentrate on where energy is generated, how energy is delivered and how energy is consumed. The first part of this lesson will concentrate on electricity and natural gas as sources of energy. The campus has a primary transformer that supplies electricity to 30 buildings. This will be treated as the entry point for all electricity in the study. The Physico-chemical and biological principles of energy generation from raw resources will be introduced as a starting point for further discussions on efficiency.

The second part of this lesson will concentrate on potable water. It will discuss where city water is gathered, how it is treated to be potable, how it is delivered, and what happens to it when it leaves the university. This lesson will use one of the public restrooms as the focal point for the study. This has been choose as a place where fresh water is required for hand washing and drinking and non-potable water is required for sanitary reasons. This complex interaction of multiple supply and waste streams forms a nice topic for study.

3.2 Resource Flow Studies

Table 1 shows an initial listing of the resource consumed, the activities these resources support and the by-products produced by these activities at a typical university. A list like this is the starting point for discussions of self sufficiency and sustainability. Once students have an understanding of what resources are required for daily activities and what by-products these activities produce, students can engage in discussions of how to reduce consumption and how to plan for shortages.

Resource	Activity/Use	By-Products
Power	Lighting	Recyclable Trash
Electricity	Heat/Cool	Non-Recyclable Trash
Heating Fuel	Travel	Excess Heat
Automotive Fuel	Cooking	Combustion By-Products
	Powering Technology	Sanitary Waste
Water		
Potable	Lawn Watering	
Non-Potable	Thirst	
	Hunger	
Food	Resource Preservation/Storage	
Perishable	Sanitation	
Non-Perishable		
Cooking Oil		

Table 1: Resource flow for typical university

Once the students have a firm understanding of what resources are used by the university the course will progress to study the effects of shortages in one or more resources. Most students will have experienced brief outages of electricity or short term boil orders for water, but most will have no experience to draw from on planning for prolonged loss of a resource. Even the developed nature of North America does not preclude the chance of losing of one or more resources for a prolonged period of time. Several occurrences in the past five years have shown that loss of electricity for a week or more is a very real possibility, and failure to plan for these occurrences can lead to significant loss of lifestyle.

The course will study how loss of one resource can lead to complete collapse of local sustainability without the proper forethought. During a wide spread loss of electricity, like the North East black out of 2003 and the primary transformer failure at Saint Louis University in the summer of 2006, leads to loss of refrigeration leading to the loss of perishable food. It leads to the closing of stores and an inability to purchase items such as food and gasoline. It leads to an inability to operate most residential heating and air conditioning. It leads to a collapse of communications systems. This lesson is intended to instil in the students ideas of how to be completely self sufficient for at least a week to be able to ride out short term disruption in resource supply.

One plan for being self sufficient is to reduce the resources that are consumed on a regular basis. This lesson discusses that learning to use a smaller amount of resources makes planning for resource interruption easier. It also discusses that reduction in certain resources allows for complete autonomy in that resource. Households that that can reduce their electricity usage below the amount that can be generated through solar and wind sources can not only be completely autonomous but they can trade excess in their electrical power for other resources that cannot be supplied autonomously.

The discussions of resource consumption culminate in a lesson that demonstrates the resource cost of daily activities. In this lesson the students go through a series of brain storming and discussion exercises to develop an approximation of the total resource cost of holding that 50 minute lecture.

3.3 Technology Dependence Studies

The course is planned to have a lesson on why technology is becoming so prevalent in our society and the dangers of relying too heavily on technology. This discussion will start with a demonstration of the students own reliance on their calculators and cell phones as a crutch to daily life and proceed through how too high a reliance on technology can lead to the crashing of localized society during resource outage. One example to be discussed is the failure of the primary computing infrastructure at Saint Louis University in 2004. This collapse was due to primary, backup and secondary electrical failure in the server room and led to the loss of primary computing resource for more than a week.

After introducing this example, the class will analyze those systems on campus that have the potential to collapse resulting in loss of intended use of campus facilities. Part of this study will include the identification of those technologies that are mission critical to the studied facilities and development of plans to maintain those critical technologies in a method that is self contained to resources local to the university.

During the identification of critical technologies the student will be asked to identify why those critical technologies are in use even though their loss would result in the loss of use of the facility. This investigation will walk the students through a learning experience that efficiency gains beyond a certain level are obtained though monitoring and online control of the systems. This monitoring and online control requires a certain level of technology.

3.4 Study of Local Disruption cause by External Interactions

Many times, disruption in local supply of resources is caused by events that are not related to events happening at the university. Studying where resources come from and the forces that can cause disruptions at the source of the resources will give the students an appreciation as to how world events cause ripples in supply chains that may not be seen locally for months or years. This type of interaction is easy to see in gasoline supply and price in the Midwest. When a hurricane approaches the Texas, Louisianan coast and off shore oil platforms are taken off line the price of gasoline in the Midwest climbs even though any actual shortage in oil will not be realized for over a month.

This study will investigate how improving efficiency in supply chains makes those supply chains less able to handle disruptions in resources. A supply chain that is operating under the mantra of just in time delivery is the most efficient due to lack of having capitol tied up in stored resources. However a one day stoppage in the supply chain can cause unexpected resource shortages down stream due to the just in time delivery of raw resources failing. An example of this that can be studied in the course is interruption in local food supply. During breaks the campus closes its restaurants and cafeterias, foreign students that remain on campus have difficulties finding food due to lack of knowledge of additional sources of this resource.

4. FIRST COMPLETED DESIGN CASE

As a first interaction between students in a course and facilities individuals we chose to do an energy audit with suggested upgrades to the Olive Compton Garage on the Saint Louis University Campus. The student involvement in this project was facilitated through a portion of a capstone experience in sustainable energy. As part of their capstone project three students performed an energy audit, suggested upgrades to the lights, and built a system that would allow some of the lights to be turned off during day light hours.

When the Olive-Compton garage at Saint Louis University started, the garage had 550 186-Watt high pressure sodium lights. For security reasons these lights were kept on all the time. The student energy audit used this 2455.2 kWh per day as the starting point in their energy audit. The students experimented with different lights and determined that an 84-Watt compact florescent light would make a suitable replacement. The compact florescent light chosen metered at a lower light output, but due to it being light with a high color temperature people surveyed reported more useful light being present. The students then found components to construct a light harvesting system to enable 150 lights to be turned off for an average of 4 hours per day and an additional 150 lights to be turned off for 2 hours a day. A nice follow on study to the garage project will be to determine how many lights are needed for security during a power failure and to design a backup system for that amount of lighting that is self sufficient for 10 days of operation.

Changing the lights to compact florescent has saved 1346.4 kWh per day and the light harvesting is saving an additional 75.6 kWh per day. This project generated several pieces of knowledge that the participating students and faculty will take forward to other projects. Even security lighting in a garage setting can consume more electricity in a day than the average house does in a month. Designing with the correct color temperature light at the correct level can cut energy usage by more than 50%. The students gained further knowledge by producing installation instructions for their light harvesting and seeing the project installed.

On the success of this initial project we are trying several studies in a sustainable energy course this semester. These projects are all feasible studies that may turn into larger capstone projects in the future. These projects include: a feasibility study to convert used cooking oil into fuel oil for either heating or vehicle use, a study of potential costs and savings of converting a campus building to ground source heat pump for HVAC, a study of using solar heating for the indoor swimming pool, and a benefits study of adding power factor correction to the large inductive loads associated with the HVAC systems on campus. The sustainable power course is currently auditing the electrical usage of the engineering building and suggesting upgrades to become more autonomous and sustainable. These upgrade investigations include replacing architectural lighting with compact florescent or LED lights, adding occupational sensors for lighting control in public areas, and offsetting grid electricity with photovoltaic and wind generated electricity.

5. CONCLUSIONS AND FUTURE ACTIVITIES

In this paper we have outlined the flow of an introductory course which introduces students to their everyday technology and energy needs. Describing the university as a small city and then drawing study examples from this description is mutually beneficial for the students, the instructor, and the facilities managers. Cases drawn from local sources are accessible, relevant, and have results that are immediately implementable.

Future activities for the course include studying the use of energy star appliances, plate exchangers, daylight harvesting sensors, and compact fluorescents. Other possible future activities for the course include investigation of energetic improvement to the University campus through such innovations as solar panels, wind mills, and clean coal stations; and water/energy saving via new technological solutions (e.g. water saving shower heads).

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EMPLOYER AND STUDENT PERSPECTIVES ON SKILLS FOR ENGINEERS IN THE TWENTY FIRST CENTURY AND BEYOND

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Abstract. This research focused on skills identified among final year engineering students. It provided evidence of different levels of skills by students and identifies their greatest learning influences in these areas. The skills were self-assessed by students and covered seven areas designated by Engineers Ireland. Competency levels such as science, software, creativity, engineering practice, social and business, ethics, discipline specific were assessed. It also investigated the important role that work placements play in skills developed by students. Key skills sought by leading Engineering firms from graduates now and in the next five years were also researched in this paper. Employers were surveyed to determine and investigate skills needed from graduate engineers and how best to meet these challenges.

The emphasis on work placements and its impact on skills' development in engineering students such as business acumen and working effectively and efficiently in industry were highlighted.

Keywords; career, competency education, Engineers Ireland competency, student surveyl.

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1. INTRODUCTION

The total number of CAO acceptances has increased steadily in recent years due mainly to rises in acceptances for level 8 programmes. Due to the significant contribution of the science and technology sector to the Irish economy, trends affecting the supply of skills to this sector are examined here in greater detail. Higher education can last from two years (leading to a higher certificate award) or three to four years in order to obtain an honours bachelor degree. Postgraduate education then follows and may range from one year for postgraduate diplomas, higher diplomas and taught masters degrees to three or more years for a doctoral qualification. It is widely accepted that students need to be career conscious, multi-skilled and motivated in an ever increasing competitive graduate jobs market [1-3]. There are four interlinked sections in the formal education system (illustrated in Figure 1): primary, secondary, further education and training (FET) and higher education [2]. Present research carried out on a cohorts of thirty five students in the final year of mechanical and manufacturing engineering degrees at Dublin City University. These groups of students, lies in the green box in the Figure 1, who are in a four year bachelor engineering degree course.

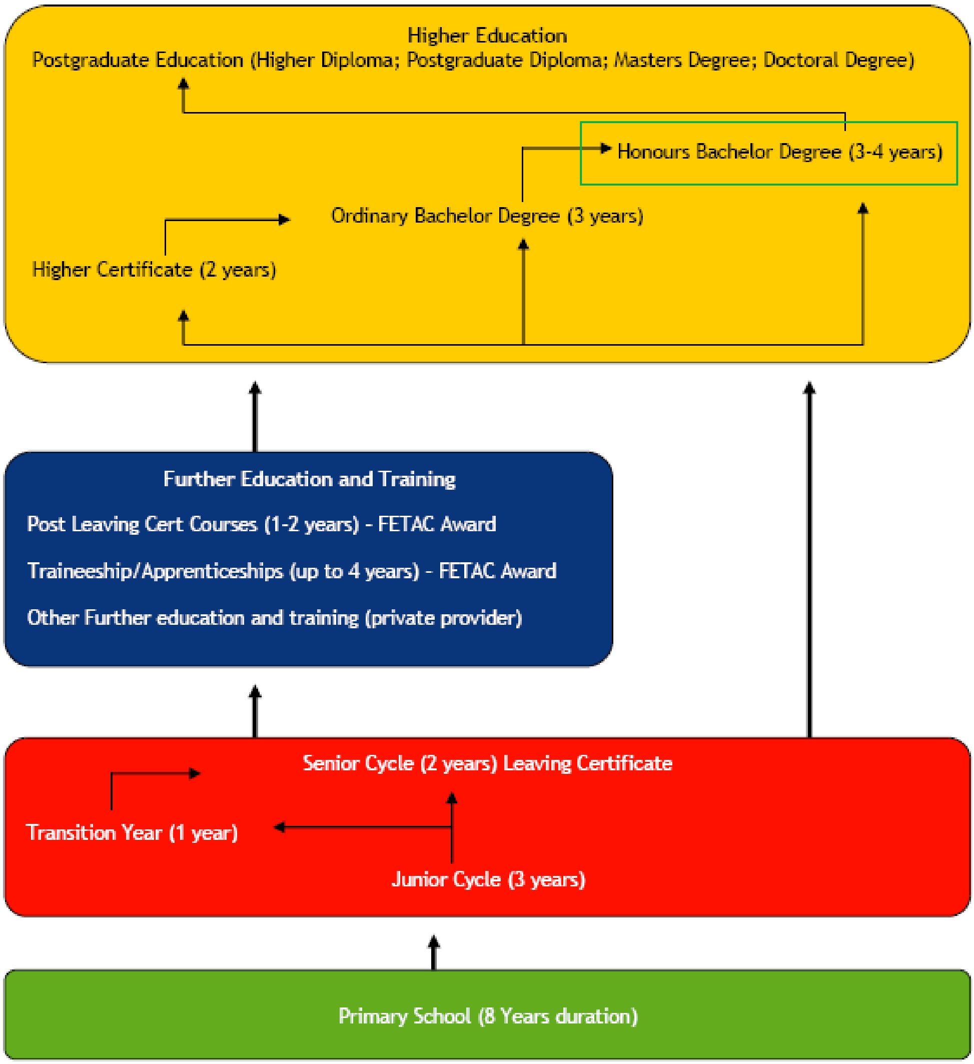

Figure 1: Formal Irish Education System [2]

2. SURVEY

Thirty five final year students in the school of mechanical and manufacturing engineering were surveyed by using a questionnaire which can be found in full in section 2.1. Fifteen leading employers have been surveyed and the Employer survey can be seen in section 2.2.

Parts one of the questionnaires was based on the leaving certificate subjects and part two was based on competency level such as since, software, creativity, engineering practice, social and business, ethics, discipline specific as indicated by Engineers Ireland accreditation criteria. A special emphasis was given to the work placement programme in DCU (INTRA), final year projects and a group project carried out all through the programme to identify improved levels of competency.

2.1 STUDENT SURVEY

The purpose of this research is to identify graduate skills acquired during your programme of study. Final year engineering/ post graduate students and leading engineering firms are being surveyed to assess skills and competency levels acquired and needed respectively. This information can help inform education providers to ensure that priority is given to developing the relevant skills in students which are needed by industry.

STUDENT NUMBER

EMAIL

TEL

What sectors are you interested in working in?

- ☐ Pharmaceutical, Chemical and Medical Technologies
- ☐ Electronics, ICT and telecommunications
- ☐ Manufacturing and Industry
- ☐ Construction and Civil Engineering
- ☐ Environmental
- ☐ Power Systems
- ☐ Others________________________

PART 1

Did you have physics in your leaving certificate ☐ Yes ☐ No

Did you have chemistry in your leaving certificate ☐ Yes ☐ No

What level of maths did you take in your leaving certificate?

Did you have applied maths in your leaving certificate ☐ Yes ☐ No

Are you satisfied overall with the level of competency you have acquired during your studies? ☐ Yes ☐ No

If not, which areas of the course would you liked to have studied more?

____

Are you satisfied with the range of subject areas covered on your programme?

____

If not what other areas would you have liked to have been covered?

____

PART 2

Please assess your level of competence in the following competency areas.

(a) Sciences and Mathematics

Biology	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Chemistry	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Physics	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Maths	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent

(b) Software and Information Systems

Programming	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
IT Skills (Internet, networking, multimedia, …)	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent

(c) Creativity and Innovation

Brain storming methods	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Product design	Very Strongly Agree	Strongly Agree	Agree	Do Not Agree	Do Not agree at all
Research methodology	Very Strongly Agree	Strongly Agree	Agree	Do Not Agree	Do Not agree at all
Team work	Very Strongly Agree	Strongly Agree	Agree	Do Not Agree	Do Not agree at all

(d) Engineering Practice

Problem Solving	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Project Management	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent

(e) Social and Business Context

Problem-solving	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Language Skills	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Oral Communication	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Written Communication	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Interpersonal Skills	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Leadership	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Continuous Learning	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Financial Awareness	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Legal Skills	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Entrepreneurship	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Multicultural Skills	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent

(f)Ethics

Health & Safety	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Industry standards	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Product regulation	Very competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Social responsibility	Very competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Research ethics	Very competent	Competent	Reasonably Competent	Not Competent	Not at all competent
Business	Very competent	Competent	Reasonably Competent	Not Competent	Not at all competent

(g) Please list any other four discipline-specific technology areas that you have learnt during your programme of study and that are not mentioned elsewhere in this questionnaire (e.g. Finite Element Analysis, Advanced Manufacturing, Advanced Materials, Automation, CAD, …)

1.____________	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
2.____________	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
3.____________	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent
4.____________	Very Competent	Competent	Reasonably Competent	Not Competent	Not at all competent

Have you completed a work placement Yes No
If yes, how relevant has your work placement being for improving your skills overall?

Relevance of work placements for development of skills	Very Relevant	Relevant	Fairly Relevant	Not Relevant	Not at all Relevant

Are there any skills which you consider very important not currently being developed as part of your studies?
____

Please indicate on a scale of 1 to 5 how much you feel the final year project, INTRA and group project work contributed to the listed learning outcomes. Where 1 stand for high contribution and 5 stand for low contribution.

Competency area	Final year project	INTRA placement	Group project work
Sciences and Mathematics			
Discipline-specific Technology			
Software and Information Systems			
Creativity and Innovation			
Engineering Practice			
Social and Business Context			
Ethics			

2.2 EMPLOYER SURVEY

PART 1: Same as Student Survey

PART 2: Same as Student Survey

Additional questions asked to the employer were as follows:

a. Are there any skills which you consider very important not currently evident in graduate engineers?
b. Are there any skills which you consider very important not currently evident in graduate engineers but will be mandatory to have in five years time?

3. RESULTS AND DISCUSSION

3.1 Student Survey

Among 35 students, 13 students would be happy to work in pharmaceutical, chemical and medical technology sector, 4 in electronics, ICT and telecommunication and 20 in manufacturing industries, 1 in construction and civil engineering, 6 in environment, and 9 in power system.

Students mentioned Stryker, Motor Sports Ferrari, Creganna, Consultant in IT/Business Accenture, Wyeth, Bayer., Capella Medical Devices, Boston Scientific, prosthetic industries like Truelife, Aerospace, ESB, AbboTt, Aerlingus, Procter & Gamble, Medtronic, oil company in Nigeria and middle east, Siemens, BMW, Eco-power generation, EFD energy, Rolls Rice in UK, Takeda, Airtricity, Wind prospect, Research and Development, Safety, ABO wind, HP, Intel, Air Bus, SEI, Retail Management, Fitness Industries, Bosch, Honda, Aquamarine.

Out of 35 students, 27 had physics, 14 had chemistry, 24 had higher and 3 had ordinary maths, only 5 had applied maths in their leaving certificate. 29 students are satisfied with their level of competency acquired during their studies. Overall 80% of the students are happy with their level of achievement from their graduate studies.

DCU, mechanical students considered themselves to be more competent in physics and maths than biology or chemistry. They have well balanced IT and programming skills. Students are creative and innovative and have a strong knowledge of ethics. Students think that they are lacking in social and business skills as they do not have any training on those. They would like to improve their legal, entrepreneurship, interpersonal and conflict resolution abilities.

In an open question in part 2g, they have indicated to have wider knowledge on CFD, CAD, FEA, Automation, signal processing, pneumatics and control. They would like to have more practical knowledge to be able to handle the equipment machined by them. Most of the students are not happy with the final year project as they felt that there are not properly trained to do the project with previous courses or training gathered from the degree. The majority of the students pointed out that LabView and more programming skills should be developed as part of the course.

3.2 Employer Survey

Ten leading DCU work placement and graduate employers partook in this survey for the purpose of this research paper. All of the companies surveyed (100%) were satisfied overall with the level of skills found in placement students and graduates in Engineering/IT. Of those surveyed, 80% found students/graduates very competent in Physics and Maths and reasonably competent in Biology and Chemistry where it was relevant to their industry. Employers were very satisfied with software and information systems abilities evident in students/graduates. The inclusion of e-commerce as part of their programme development was mentioned. The majority scored very well on creativity and innovation but appeared weaker on brainstorming activities and project management.

Results indicate that employers found graduates competent in engineering practice skills but expressed the need to develop their leadership abilities. Results also indicated the need for students to be competent in Industry Standards and Health & Safety.

Employers expressed that their professional development skills such as presentation and written skills could be improved. Some employers responded that students and graduates were shy in their initial days of employment and at interview needed to improve motivation for the roles offered. Overall their business acumen could be improved and they need to realise the reality of starting at entry level within companies.

Some employers expressed the need for more specialists training in areas such as Radiofrequency, Internet Protocol Networks. Others expressed the need to improve their industry knowledge and become more aware of what is happening in the industries which employ them.According to the research results, placement students and graduates need guidance on new technologies within the companies. An emphasis on AutoCAD is needed as part of their programme development. Legal and regulatory skills should be covered within their programmes of study as well as quality assurance. For the pharmaceutical industry employers expressed concern over the lack of awareness amongst students/graduates about clean rooms.

As we move into the next five years, there is an increased effort to reduce energy consumption and alternative energy sources need to be further development. This is an area which should be concentrated on as part of Engineering/IT programme development in the future. There are strong agreements between the students self assessment and the employers opinion on the competency level and the future competency needs.

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THE IMPACT OF SENIOR DESIGN PROJECT WORKLOAD ON STUDENT PERFORMANCE

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Abstract: Most, if not all, credible engineering programs have a senior design project as part of the curriculum. This capstone effort is intended to allow students to exercise four years of accumulated undergraduate education in the design of an object or a process. The Design Project (Mec E 460) in the Department of Mechanical Engineering at the University of Alberta aims to give the students in their senior year a realistic experience in all aspects of industrial design. These includes not only the academics that the students have undertaken in their degree but also the other duties carried out by a designer which could include, defining the problem, interaction with the client and documenting and communicating the solution. An increasing concern is the amount of work, time and stress undertaken by the students and the impact of this on their academic performance in this and other classes. Based on records kept by students, the teams have typical workloads of ~15 hours/person/week on average over the 13 week semester and this may be as high as 25-40 hours/person/week. A comparison however of the performance of these students to a second cohort of students who are not partaking in Mec E 460 indicates that there is little evidence of a significant impact on student academic performance. Students exit polls indicate that students are willing to make a significant time and personal commitment to courses with perceived value.

Keywords; Capstone Design Project, Design Process, Paperless Evaluation.

1 INTRODUCTION

Design is inherently a part of any engineering activity. The teaching of design concepts and processes is none the less limited within the scope of typical engineering undergraduate programs. A balance is required between the teaching of engineering science and the implementation of this knowledge into the development and design of devices and processes. The common vehicle for tying these two fields together is a senior design or capstone project course taken in the final year by undergraduates.

It has been recognized that there is significant potential for improving the benefit of such a course by making it relevant to industry and real-world practice (Todd et al., 1995, Dutson et al., 1997). The pedagogical approach to teaching design at the senior level has changed in recent years with more emphasis being placed on developing and utilizing design projects that are industry based (Incropera, and Fox, 1996, Todd et al., 1995) and follow a process (Farr et al. 2001). A number of approaches for linking the design project to industry, reported in the literature, have common themes (Todd et al., 1995, Dutson et al., 1997). Students are divided into teams or groups and are challenged to tackle an engineering design problem that has been sourced from industry. Different approaches have been documented for the interaction of the academic advisor with these groups; these include a supervisor, mentor or an academic resource (Harris and Jacobs, 1995, Marin et al. 1999). Problems of 'social loafing' and 'free riding' by students have been reported (Griffin et al. 2004) but root course has yet to be clearly defined. The workload hours devoted to the course on a weekly basis, varies within the literature. This depends on the duration of the course (one or two semester) and the number of group members. In some cases the capstone project is the first experience the students have at an open-ended problem typical of that found in engineering design. The review by Todd et al. (1995) of courses given in programs in the US showed that 48% allocated capstone course hours of > 7 hrs/week with some programs expecting students to finish the project regardless of time commitment. Developing management skills for both time and workload can be part of the capstone project. However, there is a potential that students can focus their efforts to a single course leading to an impact on academic performance in concurrent courses.

This paper examines the impact of student workload in a capstone design course on other courses taken. To place comments into context, a description and overview of how the capstone design course is implemented in the Department of Mechanical Engineering at the University of Alberta will be presented. This is followed by a determination of the workload of students taking the course and its influence on other courses taken simultaneously.

2 COURSE DESCRIPTION

2.1 Background

The underlying philosophy of the Capstone Design Project (MEC E 460) in the Department of Mechanical Engineering at the University of Alberta is to provide the senior students with a real world experience. In 2005/2006 the program changed from a full year (two semester) course to a single semester delivered in both Fall and Winter. This was mostly in response to a significant increase in student numbers as part of a student program expansion initiated in 2002. Currently, the Faculty of Engineering has an enrolment of 1,000 students into a common first year and Mechanical Engineering receives 180-200 students into second year. Most undergraduate courses have a traditional Mechanical Engineering flavour and as such the first real opportunity for students to exercise their breadth of knowledge and experience in open-ended problems, that can cross topics and even disciplines, is in their final year through the design project. Revision of the program to take into account the implementation in a single four month semester led to the development four features around which the course was designed. These features were: 1) use of industrially sponsored projects, 2) implementation of a rigorous design methodology, 3) a paperless environment for all course submissions and 4) a consistent approach to design at all levels of the undergraduate program. The first three features are now fully implemented in to the Capstone course.

Table 1. A list of topic headings for lectures as staged through the MEC E 460 Design Project

1. Course & Design Project Introduction	13. Material Selection & Specification
2. Design Process - Phase 1	14. Conceptual Design Drawings
3. Problem Definition & Specification Development	15. Manufacturing Methods
4. Client & Team Communication	16. Design Process - Phase 2 Report
5. Industrial Design	17. Manufacturing Cost Estimating
6. Technical & Design Research Skills	18. Design Process - Phase 3 Detail Design
7. Project Planning	19. Detail Design Analysis
8. Design Process - Phase 1 Report	20. Detail Design Drawings
9. Design Codes	21. Design Presentation - Public Speaking
10. Design Process Phase 2	22. Poster Design
11. Conceptual Design	23. Design Process - Phase 3 Report
12. Conceptual Design Analysis	

2.2 Course organization

To carry out the course project work, students are divided into groups of four students and are essentially treated as a small consulting company. This group size is due to evidence of some students not fully engaging in the course with groups of five and more and a high potential for work overload for groups of three or less. These groups have weekly, one-hour meetings with a course advisor who essentially acts as a senior engineer as part of the group. The adviser takes on the role of mentor, advisor and can become involved in creative aspects of the group however all decision-making is left to the students. The role of the adviser is not to direct the project but to fill gaps of knowledge and experience that the group does not possess. This approach allows the projects to proceed in a timely fashion.

A series of two, 50 minute lectures per week are also delivered to the students. The lecture topics covered are shown in Table 1 and the intent of the lecture series is to provide information and direction to the students as appropriate in the timeline of the project. The topics and when they are delivered are also heavily linked to the design process discussed in the next section. When appropriate, these lectures are given by or incorporate a guest presenter. These can be from within the faculty of the Department or more often, design engineers working in relevant areas in industry. The selection of lecture topics is challenging as the projects undertaken by the students are extremely varied and may range from biomedical devices to lean manufacturing to thermal systems design.

2.3 The projects and industrial sponsorship

A strong rapport has developed in recent years with local industry in providing and supporting suitable design projects for the course. The commitment on the part of industry is to set aside enough time to discuss the project with each group and to periodically field questions and critique designs. Two safety nets are built in to the course to ensure that students do not get into trouble. Each project is screened for an appropriate level of difficulty and the students have a "scope knob" that they can turn in the event that they feel that the project is growing too large for a 13 week semester. One might imagine that the student groups would take early advantage of the "scope knob" to reduce the work load but this has never been the case.

Shortly after starting the course and forming their groups the students are asked to submit a letter identifying the group members as well as first, second and third choice of projects listed on the course web site. Because the sponsors rarely want to deal with more than two groups, the number of groups working on each project must necessarily be limited. The students are encouraged to submit the letter early and are assigned projects on a first come - first served basis.

2.4 Teaching a rigorous design process

The revamp of the design courses has resulted in the implementation of a rigorous design process that is used throughout the undergraduate program. The process is broken into three phases that allow the students to focus on specific, phase related tasks breaking the larger and perhaps incomprehensible project into 'bite-size pieces'.

2.4.1 Phase 1 - Specification development and project planning

This phase is initiated with contact between the project sponsor and the student group (without advisor). Student groups are encouraged to visit the place of business of the sponsor and the purpose of the meeting is twofold: to engage the students and the sponsor and for the students to carefully listen to the sponsor so they have a better understanding of the project requirements and scope. The student groups are usually given about two weeks to complete this task as well as any background research in the general area (review codes, standards and patents in the general area). At the end of the specification development phase the student groups submit a Design Specification as well as a short written description of the problem as they understand it. This is prefaced with the usual business communications such as a letter of transmittal and is packaged as a formal deliverable.

At the same time the students are developing specifications they are encouraged to develop a project plan. This involves identification of all of the various tasks associated with the project and an estimate (no matter how far off) of the time required and an individual responsible for each task. The division of responsibilities is not rigid but lets the group divide the project into manageable parts and helps to keep it on track. The purpose of the plan is to encourage the students to look beyond the three deliverables (phases) imposed and to make sure that they complete all of the various tasks that are necessary for the successful completion of the design. It is not important if the estimates for each task are unrealistic as this is intended to be a learning opportunity. The students are asked to revise the plan, as the course proceeds, to help develop their ability as estimators. The students are also asked to keep a running record of the hours spent in the project so that they come to appreciate that these projects have a significant cost.

2.4.2 Phase 2 - conceptual design

In the conceptual design phase the students brainstorm for possible solutions and are encouraged to sketch and create solid models of potential designs. The brainstorming sessions take place in groups (a faculty advisor might be present for some or all sessions) and the students are encouraged to suggest "off the wall" solutions - not matter how bizarre they might seem. At the end of this phase (over a period of 3-4 weeks) the deliverable is a report detailing three concepts that will satisfy the project specifications. These must be shown in sufficient detail, and supported with sufficient solid models and scoping calculations, that the groups are convinced that each of the concepts would indeed work. The rationale behind three concepts is that if the requirements of the project are understood well enough, it should be possible to come up with multiple solutions. Once the brainstorming and conceptual analysis is complete the students have to decide which concept best meets the project specifications and should be carried forward to detail design - Phase 3. The students rank each alternative as to which concept best meets the design specifications and should go forward to detail design. Normally this involves the industrial sponsor, and indeed the design groups are encouraged to contact the sponsor and have them rank each alternative. The project plan is also updated as part of the deliverable.

2.4.3 Phase 3 - detail design

The final phase of the design course involves fleshing out the design chosen and finalizing manufacturing and material estimates. If the design process has been "front end loaded", then this phase is used to detail the design as much as possible. At this point there is some analysis of the scope of the work and students are encouraged at a minimum to select some aspect of the project and complete a detailed design of it. This allows the students to experience all the different aspects of a complete design. A detailed design report is submitted as a deliverable and this is used as the basis for a conference style presentation and poster to be given by the student groups.

2.5 Course deliverables in a paperless environment

Each of the phases has deliverables associated with it and these take the form of a written report with appropriate tabular material and illustrations. A listing of each of these deliverables for each phase is given in Table 2. Each of these deliverables is assessed, marked and feed-back provided by two course advisors. In this way effective communication skills, through extensive and timely feedback, are developed along with the design process. It also allows a balanced view of a subjective evaluation process.

Table 2. Course deliverables at the end of each phase of the project

Phase 1 Specification Development	Phase 2 Concept Design	Phase 3 Detailed Design
• Business format letter to the client • Design Specification Report (1,250 words) • Design Specification Matrix • Project Schedule (time lines, GANTT chart and cost estimates)	• Business format letter to the client • Abstract (350 words) • Concept Design Report (2,500 words) • Concept Specification Matrix • Project Schedule (time lines, GANTT chart and cost estimates) • Conceptual Design Calculations • Conceptual Design Drawings	• Business format letter to the client • Abstract (350 words) • Design Report (2,500 words) • Design Compliance Matrix • Project Schedule (time lines, GANTT chart and cost estimates) • Detailed Design Calculations • Detailed Design Drawings • Appendices

The second and third phases have multiple deliverables of which a major component of is in written form. Every effort is made to edit and return the Phase 2 report in a timely manner so that students can review their work and incorporate any changes in development of style into their Phase 3 reports. An innovation has been to move to a completely paperless environment with submissions being typically in PDF format. This has not only removed the cost to students of duplicating reports but has also allowed them to use other tools such as animations that can be included within the PDFs. Any restriction on page length of the report has also been removed, allowing as many figures or tables as the students feel need to be included in the report. In this case, students are encouraged to document all aspects of the report and include any extra details in an appendix. Any hand calculations can be scanned and included as well. The reports, calculations, and drawings are all graded electronically. Students submit their reports and any solid models to an online "drop-box". The PDFs are graded using a PDF editor or a tablet and pen. The word restriction on reports has been implemented both to encourage students to be concise with their writing and to also limit the amount of reading for advisors. Where appropriate, the industrial client is also encouraged to comment on the reports. Feedback from the students on the paperless environment has been overwhelmingly positive.

The final phase of the project also has other deliverables. In addition to a written report each group is asked to prepare and deliver a technical presentation to a group of peers, academic and industry judges. The presentations are a formal affair that is usually run on a Saturday near the end of the term. Since there are usually >20 design groups it is necessary to run parallel sessions in order to have everyone present in a single day. The students are encouraged to bring parents or significant others and the Department sponsors a catered lunch and coffee breaks. The presentation format is similar to a conference in that the groups each have 20 minutes to present their projects; there are five minutes for questions and a five minute change over period. All group members are required to participate in the presentation, although no one checks to see if the contributions are equal. The students take this very seriously and arrive well practiced and dressed for the occasion. The presentation is scored by the academic and industrial judges and their score is blended with the written deliverables to determine the final course grade.

The final deliverable for the course is the submission of a poster detailing each design project. The students are given a poster template, which essentially defines the size of the finished poster. It is up to them to decide what will be presented and how it will be laid out. This brings out the artistic side of some groups and the posters are innovative and unique. The department covers the cost of producing one poster per group and all posters are displayed during the formal presentations. A selection of posters from each term are framed and hung on the walls of the Mechanical Engineering building so future students can see what sort of projects have been done. The posters are graded by the course coordinators and the grade is blended with the other deliverables to assign a final grade for the course.

The breakdown of marks for each phase of the project is shown below:

- Letter of Intent (1st, 2nd and 3rd choice projects) 5%
- Phase I - Specification Report 15%
- Phase II - Conceptual Design Report 25%
- Phase III - Detail Design Final Report 35%
- Poster 10%
- Presentation 10%

The grade break down was chosen to encourage students to front end load the effort while at the same time recognize that this is a learning process. Thus the bulk of the grade is placed on the latter portions of the course (Phase III, Poster and Presentation) but there is sufficient weight given to earlier deliverables so that the students realize these are important.

2.6 Staffing level, commitment and effort

In a typical academic semester two full-time faculty members are involved in running the senior design project. These academics have typically a significant design background and level of experience from working in and with industry. The lectures are delivered by both faculty and the design groups are divided between each. The academics make a commitment to meet each of their 10 or 11 groups for a one hour project meeting per week during the term. The larger commitment on the part of the academic staff is the grading of the course deliverables in a timely manner. The students have only 12-13 weeks (depending on the year) to complete the designs. When assignments are submitted (Phase 1 - Specification, Phase 2 - Conceptual Design) there is a great deal of urgency to get these graded and returned to the students. Feed-back needs to be within a week so that the student groups can continue their designs. This means that the staff members must be able to set aside 20 or so hours to look over the students work and provide meaningful feedback. This is a significant time commitment during a marking week when student meetings are still held and, more often than not, academics still have another course to teach as well as all of the other duties and obligations to deal with. The total time spent on the senior design course the approaches 200 hours per staff member per term, far greater than most other traditional lecture courses. The use of teaching assistants (graduate students) was considered as a possibility to help with the grading and ease the work load. This idea was discarded as most of these people are not far removed from their undergraduate years and simply do not have a broad enough experience base to be really useful to the design groups.

2.7 Impact and Outcomes

Determining the perceived and real outcomes of a design course is not simplistic. Evaluation of the course has a component of subjectivity and the students are in their final year. Most students move on to their career so there is little opportunity to communicate post-degree to evaluate impact and outcomes.

All students are surveyed as they exit the undergraduate program and a number of specific questions relating to the undergraduate program are asked. Students are asked to rate the top four courses in the order in which they perceive the most value for their future careers. Data for the last three years is shown Figure 1 which lists the top 10 courses as ranked in 2009 with the total number of votes. In each of the last three years MEC E 460 clearly dominates. This indicates that the students perceive that there is significantly greater benefit and experience gained from completing the design project.

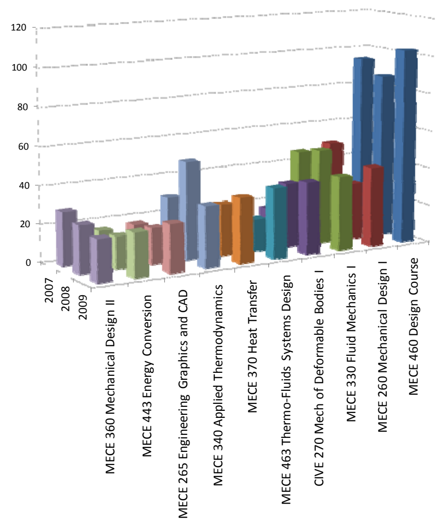

Figure 1. Listing of most valuable course as voted by students

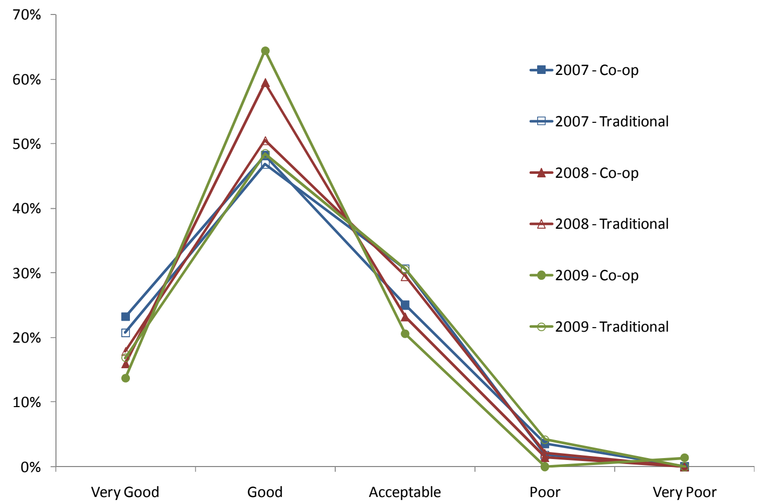

Figure 2. Perceived level of design skills of students exiting the program.

The perceived level of design skills of students is also recorded. Data for this is shown in Figure 2 for the last three years divided into two groups of students who follow a traditional track and students who participate in a co-op program. The co-op students spend four semesters working in industry while completing their undergraduate degree. In general students feel that they have good design skills on completion of the undergraduate degree. Students that have participated in the co-op program feel that they have a higher level of design skills compared to traditional students in the same year. This would indicate that experience has an impact on the level of student confidence in the design area.

As another metric to highlight the design experience gained from the course, student performance at national design competitions can be assessed. In Canada, the Canadian Society of Mechanical Engineers (CSME) organized a student National Design Competition during their annual conference. Students are judged on the presentation and communication skills as well as good design. Typically, a student team is sent from each mechanical department in the country to participate. The following is the placing of that University of Alberta student group (group name listed) at the national competition:

- 2006 –FSAE Composite Chassis 2nd Place
- 2007 –Instrumented Speedskate 1st Place
- 2008 –Electric Vehicle Propulsion System 3rd Place
- 2009 - Extra-ocular Muscle Implant 1st Place

The continued success of student groups at this national competition indicates a consistent high level of design skills is being imparted to students during the course.

3 COMPARISON OF COURSE WORKLOAD

Given the tasks of the course outlined in Section 2 and the open ended nature of design a serious concern has developed amongst faculty members as to the impact of the workload and stress of MEC E 460 on student performance in other courses. Total time, as recorded by groups, that students spent on MEC E 460 is documented in the GANTT chart submitted with final design report. Summary information on this from all groups is shown in Figure 3 and the average across groups for each phase and overall project is shown in Figure 4. On average, students spent in the Fall 2007 (F07) and Winter 2008 (F08) semesters, 14 and 16.4 hours/person/week on work related to the course. An average expectation of workload for other courses is in the order of 8 hours/person/week which would lead to a time commitment for core study for a student carrying a full work load of 5 courses of 40hours/week. This indicates that students are spending on average, approximately double the number of hours on MEC E 460. Individual data shown in Figure 3 however highlights that in many groups, that students can spend +20 hours/person/wk on the course and in some cases as high as 40 hours/person/week, doubling the expected course workload. It should be noted here that these are hours that the students commit without provocation and indeed advisors often council groups to adjust there scope / expectations for a reasonable time commitment.

As students in a single year are divided into two cohorts, one taking MEC E 460 in a single semester and a cohort that is not, a comparison can be made between the two cohorts in a single year as they swap from participating and not participating in the design course. A comparison of average student grade point average (GPA) and course load (total academic units) for the cohorts of students the 2007/2008 academic year are shown in Figure 5. The average course load is slightly higher (4%) in the Winter semester (W08) however the average GPA is essentially the same. This indicates that the extra workload and associated stress of a group of students participating in MEC E 460 does not impact on that academic performance of the students in general.

Academic performance can also be compared across courses within a given semester relative to the performance in MEC E 460. This is shown in Figure 6 where the average GPA of other course is normalized with the average GPA of MEC E 460 for class size with >10 students enrolled. This list of courses includes core as well as elective subjects and would include students enrolled and not enrolled jointly in MEC E 460. The figure shows that students perform academically better and worse when normalized this way. The average for all courses shown is 0.99 which indicates that that the extra workload and stress has no noticeable impact on students.

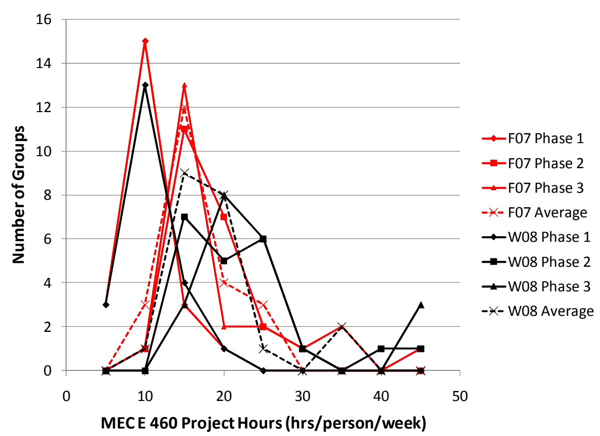

Figure 3. A histogram of student project hours for each phase of the project and overall

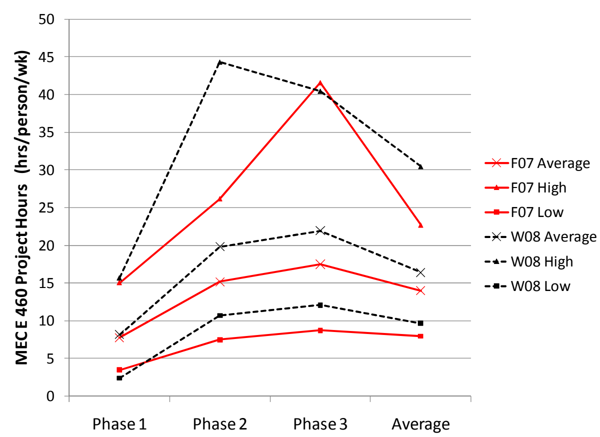

Figure 4. Average student hours per week with high and low markers

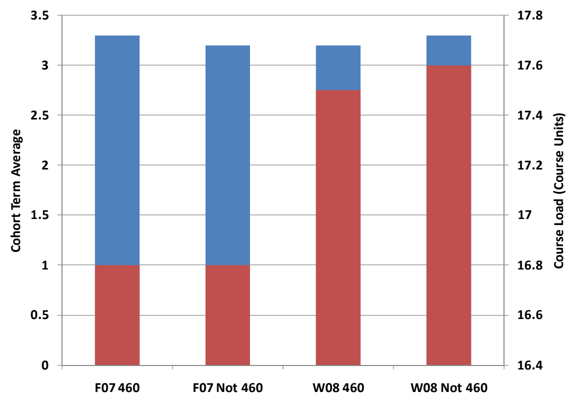

Figure 5. A comparison of student GPA (blue) and course load units (red) for cohort of students participating and not participating in MEC E 460

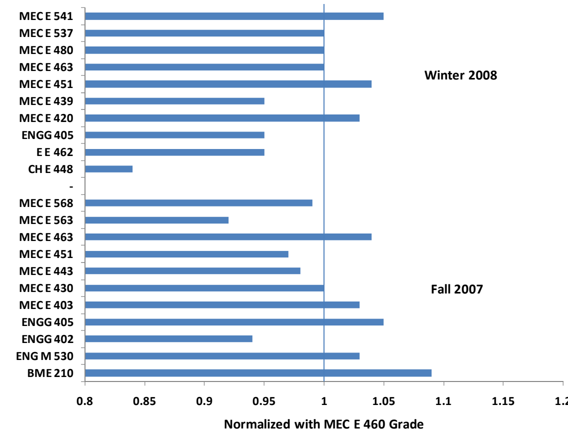

Figure 6. Average cohort GPA's scaled with MEC E 460 mark for other course taken.

4 CONCLUSIONS

A rigorous design approach has been implemented into the teaching of MEC E 460, the Capstone Design Course in Mechanical Engineering at the University of Alberta. This approach, and the open ended-nature of design, has lead to a significantly larger workload compared to other concurrent courses undertaken by students. The nature of some of the course deliverables, such public speaking, meeting and working with out-side professionals etc. also adds significant stress at a time when students are completing their engineering degree. There is however overwhelming support by the students for the experience that the course brings, evidence that the approach and knowledge imparted is impacts student performance and that there is no discernable impact on the academic performance of students in other courses. It can be concluded that given the opportunity, students will work commit significant time and effort to such a program.

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ENERGY ENGINEERING
A NEW ENGINEERING DISCIPLINE OR SIMPLY A PICK AND MIX?

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Abstract: The aim of this paper is to explore whether energy engineering is a new engineering discipline or a combination of existing disciplines. It is primarily a case study based on the experience in University College Cork (UCC), Ireland but also draws on available papers in the literature and other documented evidence from elsewhere. The paper discusses UCC's two programmes in energy engineering, a level 9 Masters Degree and level 8 Bachelor Degree. In the academic year 2009/2010, UCC attracted 290 applications for 25 places in its MEngSc Programme in Sustainable Energy. In addition, the minimum entry requirement for UCC's BE Programme in Energy Engineering was the highest for any undergraduate engineering programme in Ireland (510 points). This demonstrates the demand that exists for energy engineering programmes. The paper explores whether energy engineering is a new topic area in engineering, whether it is similar in this respect to building services engineering or environmental engineering. It also discusses whether in fact civil, mechanical and electrical engineering are the core disciplines or whether engineering itself is the only discipline. It concludes that energy engineering is certainly more than a pick and mix, that it is necessary and is here to stay.

Keywords; engineering education, energy engineering, discipline, Ireland, third level.

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1. INTRODUCTION

Over the past five years, University College Cork (UCC) in Ireland has developed two engineering degree programmes, a level 9 Masters (MEngSc) Degree in Sustainable Energy and subsequently a level 8 Bachelor (BE) Degree in Energy Engineering. These new programmes build on the research interests of UCC's engineering academic staff and complement existing undergraduate and post-graduate programmes in the more traditional engineering disciplines, namely civil and environmental engineering, electrical and electronic engineering, process and chemical engineering and mechanical engineering.

In the academic year 2009/2010, UCC attracted 290 applications for 25 places in its MEngSc Programme in Sustainable Energy and was the most sought after engineering post-graduate programme. In addition, the minimum entry requirement for UCC's BE Programme in Energy

Engineering was the highest for any undergraduate engineering programme in Ireland (510 points). This demonstrates the clear demand that has developed for energy engineering programmes.

A question that arises however, is whether energy engineering is a clearly defined new engineering discipline, or is it a combination of existing engineering disciplines that focuses on a key emerging area of interest, economic activity and employment ? This paper attempts to address this question using the experiences within UCC to carry out a case study analysis.

Section 2 traces the origins and development of the taught Masters Programme in Sustainable Energy. Section 3 discusses the evolution of the BE undergraduate programme, highlighting some interaction with stakeholders. Section 4 discusses the issues surrounding discipline and Section 5 provides some conclusions.

2. MENGSC IN SUSTAINABLE ENERGY

UCC launched its MEngSc in Sustainable Energy in 2005/2006, the first institution in Ireland to offer such a programme. The programme was developed by UCC's Faculty of Engineering, which had been involved in research, applied research and demonstration projects in the field of sustainable energy for over 25 years. It was designed to harness UCC's research experience (Ó Gallachóir, 2005) into a structured teaching programme at postgraduate level to meet growing demands.

2.1 Demand

The demand for the MEngSc programme had two dimensions, the evidence internally through increased applications for post-graduate training and the external market driving further expected steep growth.

The number of applications from graduate engineers responding to postgraduate positions offered in the field of sustainable energy in UCC and those requesting a postgraduate programme in sustainable energy[1] had grown significantly between 1999 and 2004. There were 26 applicants for an EU Marie Curie Post-Doc position in 2000, 51 applicants for postgraduate and post-doctoral positions in 2001 and 36 applicants for an EPA funded Masters in 2003. These numbers relate to Civil and Environmental Engineering alone and even at that are incomplete.

2.2 Focus

The learning objectives of the MEngSc in Sustainable Energy focus on equipping the students with the information base and skill set to actively participate in this growing global market where energy / environment policy and technological innovation meet. The objectives are to provide the students with knowledge and understanding of

- energy trends, their impacts on the environment and the engineering solutions to mitigate the damage

[1] In the absence of a taught programme most applications were for a Research Masters and to a lesser extent for Doctoral studies.

- engineering of individual renewable energy sources of wind, hydro, biomass, wave, solar and geothermal
- energy conversion processes for electrical, thermal and transport energy supply
- the integration of intermittent renewable energy with the electricity network
- sustainable energy end use in building design, construction and management
- modelling sustainable energy systems incorporating technical and financial engineering, energy market structure and dynamics and fiscal policies.

It provides graduates from any engineering discipline with a programme comprising taught modules and a research dimension. The taught modules cover renewable energy technologies (wind, ocean, bioenergy, hydro, solar and geothermal), energy end use and systems in buildings, electrical power systems, energy policy and energy systems modelling. The research provides the students with an opportunity to develop greater depth of knowledge in one of these areas through two stages, a preliminary research project and a minor thesis.

Within the field of energy engineering, sustainable energy was rapidly evolving as technological advances are made in all elements of sustainable energy deployment, e.g. wind turbine design and control, building energy management systems, fuel cell development and the emerging hydrogen economy. The course was designed to provide students with the opportunity to become aware of the latest developments and innovations and also to appreciate the interdisciplinary nature of this subject.

2.3 Distinctness

The MEngSc programme is deliberately not restricted to renewable energy supply technologies. Indeed, some elements relating to renewable energy technologies contain similar content to renewable energy supply course available in a small number of European universities. The programme however also covers additional topics that UCC also has a track record and expertise in, namely energy end use (in particular energy systems in buildings), and enabling sustainable energy policies.

2.5 Progress to Date

There were 20 applicants in the first academic year 2005/2006. This increased year on year to 77 in 2006/2007, 122 in 2007/2008, 155 in 2008/2009 and 290 in 2009/2010. While the entry requirement is for a level 8 BE degree with a minimum 2H2 grade, the majority of successful applicants in the current academic year had secured a 1H degree. The student quota is 25 and this is limited by the number of permanent academic staff available to supervise the minor theses in the summer months.

In December 2009, there were 18 graduates of the programme, of whom 14 secured a Distinction (i.e. greater than 70%). They will join the others who are engaged in Doctoral research in energy engineering or who are working in Airtricity, Bord Gais, Eirdata, ESB, ESBI, SEI and SWS to name a few employers. Regarding the former point, there are currently six graduates from the MEngSc Programme undertaking PhD research in UCC’s Environmental Research Institute.

3. BE IN ENERGY ENGINEERING

Building on the success of the MEngSc Programme, UCC launched a BE in Energy Engineering in 2008, again the first institution in Ireland to do so (Ó Gallachóir and Kavanagh, 2007). This followed two years of programme development, internal discussions within UCC, consultation with industry and external peer review.

The BE Degree covers the many dimensions of energy engineering i.e. sourcing, assessing, designing, converting, transmitting and supplying useful energy to meet our needs for electricity, transportation and heating and cooling.

3.1 Programme content

The discussions within UCC regarding the structuring this new programme raised a number of interesting questions regarding the 'distinctness' of the other established engineering programmes.

As with all undergraduate engineering programmes, the student learning experience is a layered one, with a mathematical and scientific underpinning. The 1st Year of the curriculum is dominated by foundational subjects in physics, mathematics, applied mathematics and chemistry. This raised a question – should we use the applied mathematics modules that are taught to electrical engineering undergraduates, or to civil engineering undergraduates? The process of formulating the 1st Year Energy Engineering programme has pointed to and questioned the differences between the 1st Year of the existing programmes. This in turn has lead to a rethink with a proposed rationalisation of modules and a move towards a common 1st Year in engineering. In this way, 1st Year Energy Engineering is effectively a 'pick and mix' but the resulting content is likely to be mirrored in the other programmes.

The 2nd Year of the Energy Engineering Programme could certainly be described as a 'pick and mix' in that it draws together the fundamental engineering modules from civil, mechanical and electrical engineering, including fluid mechanics, thermodynamics, heat transfer, electronic circuits and power engineering. Interestingly, the 2nd Year set of modules is the only set of modules that are drawn entirely from established existing programmes. However, no other engineering degree currently contains this combination of modules that form the basis for most disciplines and are essential building blocks for energy engineering. Indeed, it could be argued that the 1st and 2nd Year Energy Engineering programme forms the basis for a common 1st and 2nd Year for all engineering programmes.

The 3rd Year starts to show the distinct identity of this programme through the inclusion of energy specific modules such as Energy in Buildings, Sustainable Energy, Energy in Transportation, in addition to carefully selected modules from electrical engineering (Power Electronics, Electrical Machines), from civil engineering (Hydraulics, Engineering Construction) and mechanical engineering (Applied Thermodynamics, Mechanical Systems). This is further reinforced in 4th Year with clearly energy specific modules in Wind Energy, Ocean Energy, Bioenergy and Energy Systems in Buildings again combined with more familiar modules such as Electrical Power Systems and Applied Power Electronics.

The structure of the programme demonstrates that it is both a new distinct engineering programme in addition to drawing extensively on relevant existing modules from other programmes.

The programme differs substantially from other UCC engineering degree programmes in that it is designed in an integrative manner: the foundation subjects developed in the first three years lead to a focused fourth year that is designed to ensure that graduates possess all the principal knowledge strands required by the energy sector. The discipline also requires a broad but well-definable set of skills which are packaged within the fourth-year programme. Providing the students with this targeted set of skills is the paramount learning objective of the programme.

The professional and industrial focus of the programme is highlighted by the inclusion of a paid work placement of approximately five months duration between the third and fourth years, while fourth year includes a major design exercise. The professional requirements for subjects such as ethics and economics, the ability to communicate well and to work in teams are all infused into the programme.

3.2 Is this Programme Unique?

UCC is the first university in Ireland to provide such a level-eight programme. While it is not the first university internationally, it remains one of a small number of institutions internationally offer engineering undergraduate programmes focussing specifically on energy engineering.

Stanford University offers a Degree in Energy Resources Engineering. Penn State University's has an energy engineering programme since Autumn 2007. University of New South Wales has been offering a B.E. degree in Renewable Energy Engineering since 2003 and also has a B.E. degree in Photovoltaics and Solar Energy.

Additionally, several courses currently focus on a subset of the energy engineering discipline or have energy as a partial focus of the degree including

- In the island of Ireland, Limerick Institute of Technology offer a Bachelor of Science in Renewable and Electrical Energy (Level 7) and the University of Ulster Engineering Faculty offer a B.Eng.(Hons) in Building Services and Energy Engineering.
- In Britain, Heriot-Watt School of Engineering and Physical Sciences offer a B.Eng.(Hons) in Mechanical Engineering with Energy Engineering; the University of Leeds offers both a B.Eng. in Chemical and Energy Engineering and a BEng in Energy and Environmental Engineering
- Further afield, the University of Reykjavik and the University of Northern Texas both offer degrees in Mechanical and Energy engineering.

3.3 Progress to Date

In September 2008, 24 students registered for the 1st Year of the BE programme in Energy Engineering. It proved a very attractive programme with entrants requiring the highest minimum entry points (535 points) of all engineering degree programme in Ireland (Ó Gallachóir, 2009). In the second year, the entry points for incoming students remained higher than other programmes (510 points) even though the quota was raised and 37 1st Year students were admitted.

The programme has met and addressed a number of teething problems and is evolving with a number of streams of modules that progress over the four years to enable graduates to engage with the many facets of energy engineering whether it be a focus on energy in buildings or transport, or on power systems, renewable energy supply or energy policy and modelling.

4. NEW DISCIPLINE OR NEW TOPIC AREA?

The programme is certainly a new programme, but does energy engineering represent a new discipline or is it just responding to a market need? During the course of internal discussions within UCC, engagement with industry and discussions subsequent to the launch of the BE in Energy Engineering programme, this question arose.

There is consensus that the energy sector is growing and requires engineers. Since there exists already an energy industry, clearly there are people working as energy engineers, in the sense that they are working in the areas covered by: sourcing, assessing, designing, converting, transmitting and supplying useful energy to meet our needs for electricity, transportation and heating and cooling. These engineers have typically been trained in one of the traditional disciplines, namely as civil engineers, electrical engineers, mechanical engineers or process engineers. They subsequently may have received in-house training and are working in the energy industry.

One of the questions asked during the early stage discussions with the energy engineering industry was, ‘why do we need specifically energy engineers?’ and this gets to the core of the question of whether energy engineering represents a new topic area as a minimum and if so, does it go further and represent a new discipline or not.

4.1 Environmental Engineers / Building Services Engineers
It is instructive to consider environmental engineers, building services engineers, and the same question could be asked here. These represent distinct topic areas within engineering that draw on the core engineering disciplines. They require specific skill sets, represent specific job titles and professional bodies but do represent engineering disciplines?

Emerging alongside the growth of activity within the energy sector is an increase in job advertisements that use ‘Energy Engineer’ as the position title. This is anticipated to continue as the sector grows in line with energy demand growth and investment in energy infrastructure. There is a danger in developing programmes that respond to short term market demand but in the case of energy, due to the requirements and challenges that exist, it would seem unlikely that demand will diminish.

4.2 Is ‘Engineering’ the only discipline
Another way of approaching the discipline question is to ask whether the future energy engineering graduates could be employed as civil engineers, or as electrical engineers, i.e. are they being trained effectively as engineers with a hint of energy?

As the four years progress, there are more instantly recognisable energy modules, in particular in third year (for example Energy in Buildings, Transportation and Energy) and fourth year (Wind Energy, Bioenergy, Energy Systems in Buildings, etc.) The programme is structured with a focus on energy engineering from the outset however. The elements relating to electronic engineering that are not core to energy engineering are excluded. Similarly the graduates will not have the core elements of civil engineering except those that are also relevant to energy engineering. The streams of energy engineering (energy in buildings, power systems, renewable energy supply) are traceable throughout the four years in a way they are not found in any other engineering programme and thus the training is different in terms of focus and learning outcome.

To a certain extent all engineering graduates should be able to work in all engineering positions, with due training and experience, given that the building blocks are similar, an approach to problem solving, the elements of design, etc. Can environmental engineers work as electrical engineers and vice versa? Is ‘engineering’ the only discipline, and are civil, electrical and mechanical engineering just topic areas?

5. CONCLUSIUON

This paper attempts to demonstrate that energy engineering is certainly more than a pick and mix of existing disciplines, in that it adds new elements and topics within engineering in addition to drawing on existing elements that are relevant too energy engineering.

Whether or not it represents a new engineering ‘discipline’ depends on how discipline is defined.

Whatever the answers to these questions, energy engineering is growing apace as a sector that requires specifically trained graduates and the evidence shows that it’s an appealing choioce for students. To conclude, the external reviewer to the BE Programme (who hails from MIT) closed his review with ‘I wish my institute would launch the same initiative and produce an energy engineering program as well!’

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ANALYSIS OF ENGINEERING STUDENTS LEARNING STYLES ON LEVEL 7, LEVEL 8 AND LEVEL 9 PROGRAMMES

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Abstract: This contribution reports on research, carried out over three academic years, into the learning styles of engineering students, on a number of Level 7, Level 8 and Level 9 programmes at DIT, using the index of learning styles survey developed by Felder and Soloman (1991). The contribution explores the results obtained in detail, placing them particularly in the national context. The correlation between student performance and individual learning styles is examined. Knowledge of the strongly visual learning style of these cohorts of students may be used to improve the learning environment.

Keywords; learning styles, engineering students.

1. INTRODUCTION

In a seminal paper, Felder (1988) suggested that engineering students (in particular) have four dimensions to their learning styles. Each of the dimensions is described in opposite terms (active versus reflective, sensing versus intuitive, visual versus verbal and sequential versus global). In summary, active learners learn by trying things out or working with others, while reflective learners learn by thinking things through or working alone; sensing learners are oriented towards facts and procedures, while intuitive learners are oriented towards theories; visual learners prefer visual representation of presented material, while verbal learners prefer written or spoken explanations; sequential learners learn in incremental steps, while global learners are systems thinkers who learn in large leaps. Felder measures student learning styles by means of an Index of Learning Styles (ILS) on-line survey (Felder and Soloman, 1991), composed of 44 multiple-choice questions, with two possible answers for each question. In a series of papers, Felder and co-workers (e.g. Felder *et al*., 1998; Felder and Spurlin, 2005) suggested that most engineering students are active, sensing, visual and sequential learners.

A considerable number of studies have been preformed using the ILS questionnaire, both in Ireland (e.g. Seery *et al*., 2003; Cranley and O'Sullivan, 2005; Byrne, 2007; Ni She and Looney, 2007; O'Brien, 2008; O'Dwyer, 2008, 2009) and internationally (e.g. Montgomery, 1995; Rosati, 1999; Zywno, 2002; Felder and Spurlin, 2005). This paper extends the work of O'Dwyer (2009), who reported on the learning styles of Level 7, year 1 students over two academic years, by considering the learning styles of students following a number of engineering programmes at Levels 7, 8 and 9, over three academic years.

The Level 7 student cohorts surveyed were enrolled on Year 1 of the DT009/DT016 electrical engineering, DT006 mechanical engineering and DT003 automation engineering programmes. The Level 8 student cohorts surveyed were enrolled on Year 3 of the DT235 medical physics and bioengineering, and Years 1 and 4 of the DT021 electrical/electronic engineering programmes.

The Level 9 student cohorts surveyed were enrolled on the DT092 advanced engineering, DT087/DT088 mechanical engineering, DT702/DT703 sustainable electrical energy engineering, DT704/DT705 pharmaceutical process control and automation and DT015 energy management programmes. In all cases, the on-line ILS survey form was printed out, distributed to the students for completion in week 1 of the author's modules and the survey results were collated. A summary of the results, with explanations, and how the average results would inform the author's subject teaching in the semester was provided to the students in week 2 of the module; in addition, each student received their own individual survey result. Of the 243 students in the Level 7 class groups, 208 completed the survey form, giving a response rate of 86%. Of the 85 students in the Level 8 class groups, 71 completed the survey form, giving a response rate of 84%. Of the 138 students in the Level 9 class groups, 126 completed the survey form, giving a response rate of 91%. Thus, of the 466 students in all of the class groups, 405 completed the survey form, giving a response rate of 87%. It should be mentioned that student participation was voluntary, with no student exposure to any risks or reprisals for refusing to participate (as in the study performed by Zywno, 2002).

2. ANALYSIS

The data was analysed and the learning style preferences (in percentages) are recorded in Table 1 for the student cohorts surveyed. Table 1 also shows data from other engineering student cohorts in Ireland; data from engineering student cohorts in the USA, Canada and Brazil are available elsewhere (Montgomery, 1995; Rosati, 1999; Felder and Spurlin, 2005). The table structure is similar to that used in a table by Felder and Spurlin (2005), with *A*, *S*, *Vs*, *Sq* and *N* standing for Active, Sensing, Visual, Sequential and Number (of students), respectively. Thus, for example, of the 208 Level 7, Year 1 students who completed the survey in the 2007-10 period, 66% were classed as active learners (and by implication 34% were classed as reflective learners), 75% were sensing learners (so that 25% were intuitive learners), and so on.

Table 1: Reported learning style preference in percentages.

Sampled Population	**A**	**S**	**Vs**	**Sq**	**N**
Level 7, Year 1	66%	75%	93%	67%	208
Level 8, Years 1, 3 and 4	66%	62%	90%	56%	71
Level 9	56%	78%	94%	58%	126
Overall DIT engineering students surveyed	63%	73%	93%	62%	405
Second Level Students. Mean age 16.4. Studying Engineering for the Leaving Cert (Seery *et al*., 2003)	70%	79%	91%	58%	163
LIT engineering students; predominately Year 1 data (O'Brien, 2008)	70%	80%	86%	54%	101
Cranley and O'Sullivan (2005):					
IT Tallaght, Level 7, Year 1, 2002-3	81%	63%	85%	29%	-
IT Tallaght, Level 7, Year 1, 2003-4	78%	52%	88%	26%	-
IT Tallaght, Level 7, Year 1, 2004-5	69%	67%	76%	37%	-
UCC, Process and Chemical Engineering (Byrne, 2007)	45%	70%	82%	68%	38

The DIT student cohort results, as revealed by this table, are compatible in broad terms with other such results and with Felder's conclusions, mentioned previously, that most engineering students are sensing, visual, active and sequential learners. Strikingly, the DIT student cohort tend to be very visual learners.

More detailed analysis of the data is shown in Figures 1 to 4, in which strengths of the reported preferences are indicated for the DIT Level 7 and Level 9 students surveyed. Separate analysis is available for the Level 8 students surveyed, though the profiles generated are similar to those shown and are excluded for clarity. Having completed the survey, each learner is assigned a point on the scale from –11 to +11 for a given dimension. For example, in the active-reflective dimension, a learner scoring –11 is a strongly active learner, with a learner scoring –1 being a marginally active learner.

Clearly, there are similarities in student profiles for the sensing-intuitive, visual-verbal and sequential-global dimensions, with some differences in the active-reflective dimension; the difference shown in this dimension is as expected, considering the level of the student cohorts. The results in Figures 2 to 4 point to an interesting contrast to the conclusion of Zywno (2002), who suggests that there is a shift in distribution of learning styles between, in this case, first year and final year students on the equivalent of a Level 8 programme. The similarities of the profiles for the two DIT student cohorts suggest that the learning style survey would not be useful as a diagnostic tool to predict first-year Level 7 students who may be in danger of not progressing to the second year of their programme. This is confirmed by a statistical analysis performed by the author for the data available from DIT students on one Level 7 programme in the two academic years from 2007-9, in which it is clear that learning styles and performance at assessments are not correlated in a statistically significant way. For example, the p value for the relationship between the terminal examination mark and the sequential-global scale is 0.43 (n=55). Therefore, the author has not found the link suggested between extreme learning style and lack of achievement in summative assessments, for a similar cohort of students at IT Tallaght, by Cranley and O'Sullivan (2005). In contrast, other work performed by the author shows that there is a highly statistically significant relationship, for example, between the terminal examination marks and lecture attendance over the two academic years for the DIT students mentioned above (p=0.0006, n=66).

Overall, a large percentage of both cohorts of DIT students have no strong learning styles preferences, except for the Visual-Verbal category, for which a large majority of students have a moderate or strong preference for visual learning. Interestingly, among the Level 7 students, a majority of students show no strong preference for active learning; traditionally, Level 7 programmes place particular stress on active learning in laboratories and workshops.

Figure 1: Active versus reflective learners

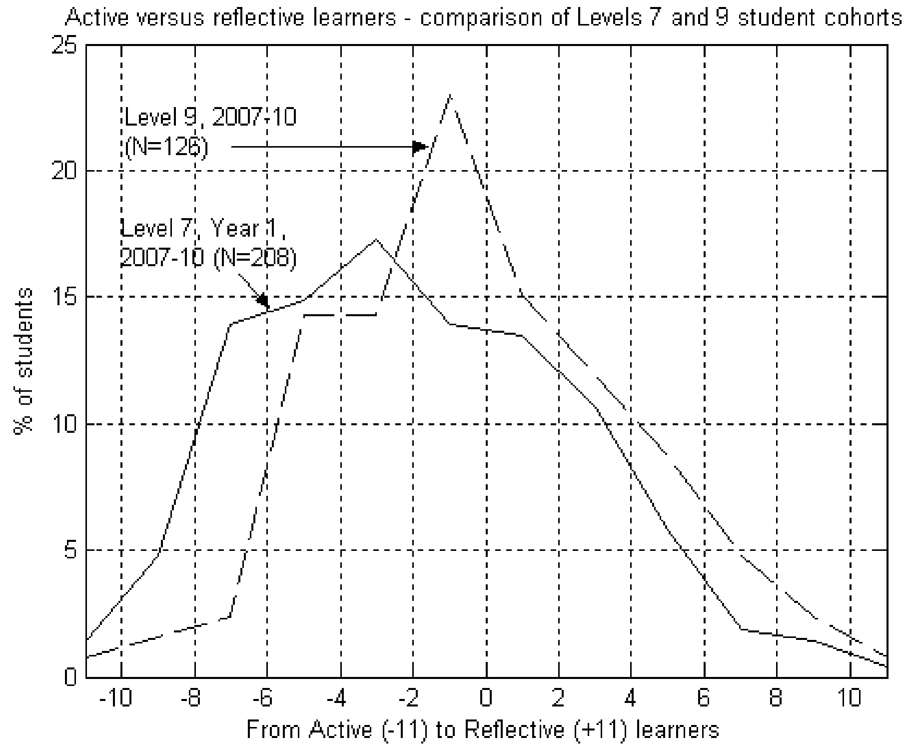


Figure 2: Sensing versus intuitive learners

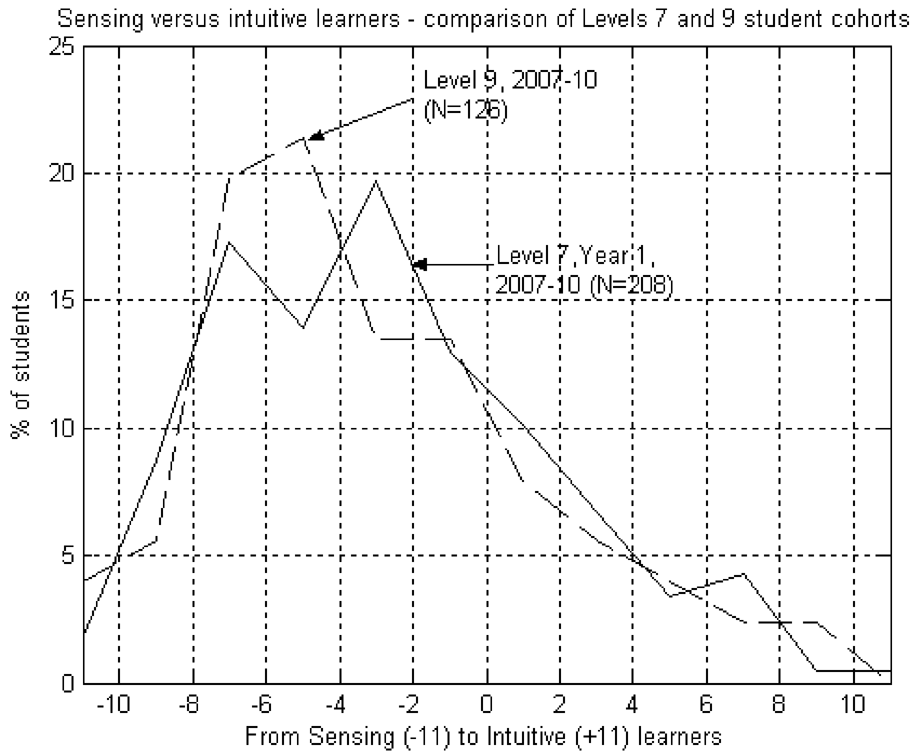


Figure 3: Visual versus verbal learners

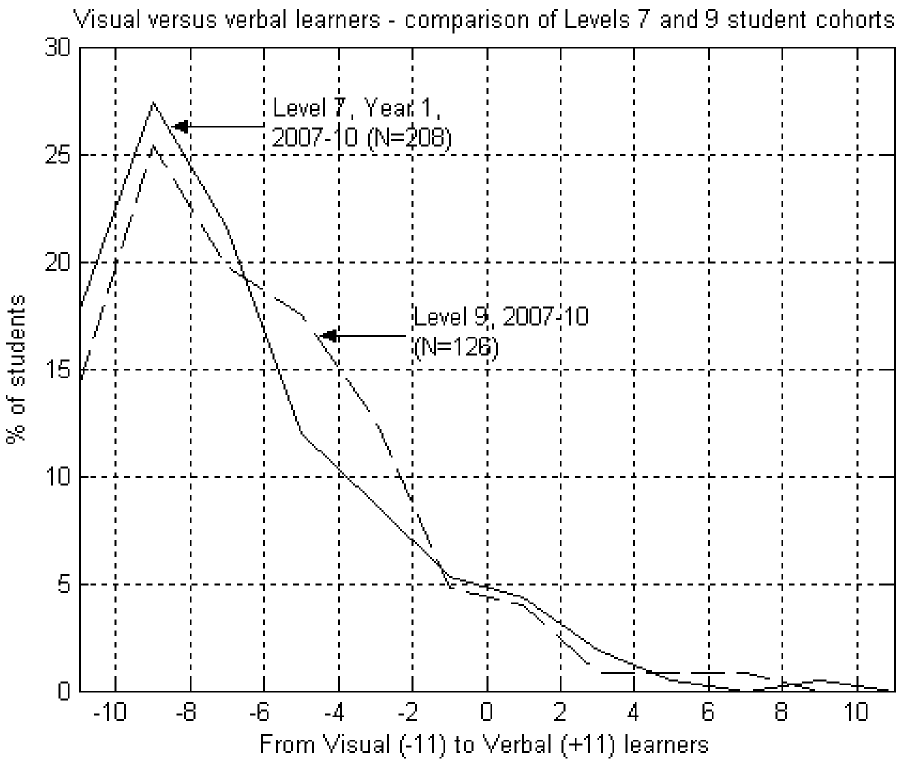
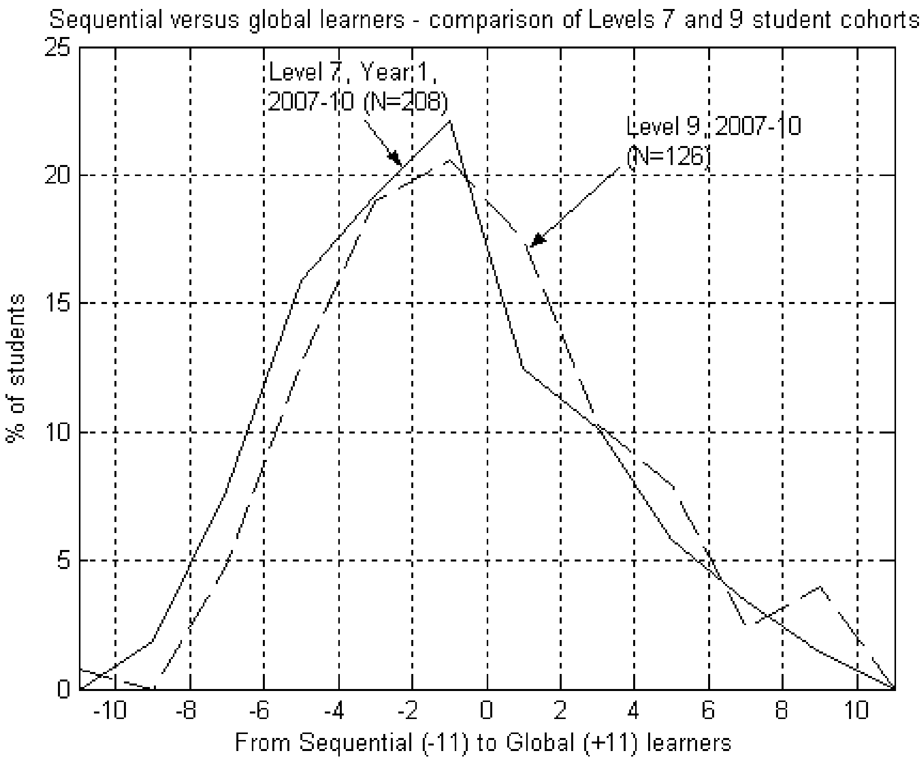


Figure 4: Sequential versus global learners



3. DISCUSSION AND CONCLUSIONS

The index of learning styles survey is a useful tool to identify the most preferred student learning mode, for both student and lecturer. It facilitates rapid feedback to both, and allows the lecturer to tailor, to some extent, both teaching techniques and assessments to the clear visual learning preference that is evident from the survey results. More generally, the author has found that learning style profile, as measured by the survey of Felder and Soloman (1991), and performance at assessments are not correlated in a statistically significant way. However, there is some evidence that a link exists between assessment performance and student learning style, using other surveys which are based on Kolb's learning style inventory (e.g. Cagiltay, 2008). Thus, it seems reasonable that the tailoring mentioned above should allow improvement in the student retention rate. It is desirable to create an overall learning environment across all subjects to appeal to as wide a range of learning styles as possible; teaching methods to reach students who span the spectrum of learning styles have been suggested by Felder (1993), for example.

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EXPERIENCES OF TEACHING, LEARNING AND ASSESSMENT OF STUDENT RESEARCH SKILLS ON A LEVEL 9 TAUGHT PROGRAMME IN ENGINEERING

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Abstract: This contribution reports on the teaching, learning and assessment of a Research Methods module on a Level 9 taught programme in engineering at DIT. The module was run in the 2008-9 and 2009-10 academic years. The module is a generic one, whose aim is to facilitate students in developing a comprehensive proposal for their engineering research project. A team approach was taken to module instruction. Students were assessed (at different stages during the module) by evaluation of a written research proposal planner document, a reflective PowerPoint presentation and a final written research project proposal. The contribution reflects on the module experience, including the lessons learned and the proposed further development of the module.

Keywords; research methods, level 9.

1. INTRODUCTION

The Faculty of Engineering of the Dublin Institute of Technology (DIT) introduced, in September 2002, a programme leading to a ME degree in Advanced Engineering. To respond to changing requirements, this programme was replaced by four denominated ME programmes in September 2008 (in *Mechanical Engineering*, *Sustainable Electrical Energy Systems*, *Pharmaceutical Process Control and Automation* and *Signal Processing*). These programmes can be taken on a full-time or part-time basis. The programmes are semesterised and modularised, allowing learners to advance from a Postgraduate Certificate (on completion of six taught modules or 30 ECTS credits) to a Postgraduate Diploma (on completion of twelve taught modules or 60 ECTS credits) to a Masters degree (on the completion of twelve taught modules and an engineering project or projects, a total of 90 ECTS credits). Single module certification is also available. Full details of the programmes are available (DIT, 2010).

Research Methods is a core module, shared by all of the ME programmes. The module learning outcomes are that, on successful completion, the learner will be able to:
- Construct a strategy to conduct research;
- Appraise and evaluate library resources applicable to their research at postgraduate level;
- Write a literature review relevant to the research proposal;
- Demonstrate an ability to critically evaluate all aspects of their research;
- Develop a research proposal for a research project and develop a plan to complete the project;
- Write and present a research proposal.

The module is continuously assessed. The final outcome of the module, weighted most heavily for (summative) assessment, is a student-written research project proposal; in this proposal, it is expected that the research questions would be identified, the literature review developed, the research methodology made clear and the significance of the study established.

Modules with similar learning outcomes are now common on taught engineering postgraduate programmes in Ireland (e.g. TCD, 2008; UCC, 2009; UCD 2009; DCU, 2010; WIT, 2010) and internationally (e.g. Oregon State University, 2009). Most modules focus on skills development in topics such as information literacy and dissertation writing, though some cover other topics, such as statistical analysis techniques (e.g. DCU, 2010). Increasingly, interesting papers are appearing on aspects of this work (e.g. Hill, 2006; Holles, 2007; Antonesa and McAvinia, 2008; Willison, 2008), though experiences remain underreported, particularly in the Irish context.

At DIT, it was decided to run the Research Methods module in Semester 1, to prepare students for the engineering project which could start in Semester 2 for full-time students; part-time students have a more flexible date to start project activity. A team-based approach was taken by instructors in designing the learning activities for the module. The author was responsible for running a series of student workshops, in which students worked in teams, in a brainstorming environment, to solidify project topics and ideas. Student work was underpinned by workshops, delivered by the author's colleagues, on information literacy, technical writing, critical thinking, the research funding process, and intellectual property and patenting issues.

2. EXPERIENCES 2008-9

The module was first run in the 2008-9 academic year, and 17 full-time and part-time students, drawn mainly from the Mechanical Engineering stream, took the module. The learning schedule is outlined in Table 1.

Week	Topic	Lecturer
1	Research methods module outline. The research project. Overview of current research activity in the Faculty of Engineering. Criteria for research proposal assessment. Proposal planner.	A. O'Dwyer
2	'Brainstorming': Student presentation of thoughts on their research topic.	A. O'Dwyer
3	Feedback of results of brainstorming session. Research methodologies.	A. O'Dwyer
4	An introduction to literature reviewing. Using library resources.	J. de Foubert
5	Devising search strategies. Identifying and using relevant e-resources.	J. de Foubert
6	Review Week	
7	Current awareness services for research. Plagiarism issues. Review search strategies and literature review progress.	J. de Foubert
8	*Formative assessment: Student presentation of a short literature review of their chosen research topic, plus a reflection.*	Team
9	Critical thinking, CoRT (Cognitive Research Trust) thinking techniques.	D. Gordon
10	Technical writing.	T. Burke
11	The funding process, sources of funding, how to apply for funding, how to manage a funded project.	M. Rebow
12	IP and patenting issues.	M. Rebow
13	*Student presentations on research proposal. Tutor marking. 30% of mark.*	Team
	Week 16: Submit 4000 word research proposal report. 70% of mark.	Team

Table 1 Learning schedule for module: 2008-9.

Overall, the research proposals produced were of a satisfactory standard. Upon reflection at the end of the module, examining student feedback, and after discussions with the course directors of the engineering streams, the following actions for improving the module experience were identified:

- A rebalancing of the assessment, so that it occurs more evenly throughout the module;
- The production of clear assessment criteria for students, with student involvement in assessment;
- The greater use of workshops;
- Encouraging a better link between the research proposal and the research project;
- Submission of research proposal reports electronically, allowing the use of anti-plagiarism software as an option;
- Clearer academic responsibility for the module, with closer co-ordination of module activities.

3. EXPERIENCES 2009-10

The module was run for the second time this academic year and was completed by 59 students, 30 students on the Mechanical stream, 17 students on the Sustainable Electrical Energy stream and 12 students on the Pharmaceutical Process Control and Automation stream. Of these 59 students, 50 were following their programme on a full time basis. The increase in student number and diversity, coupled with the lessons learned from the module experience in the previous academic year, prompted the development of the learning schedule summarised in Table 2.

Week	Topic	Lecturer
1	Workshop 1: Research methods module outline. The research project. Overview of current research activity in the Faculty of Engineering. Criteria for research proposal assessment. Proposal planner.	A. O'Dwyer
2	Library resources, search strategies, current awareness services for research. Plagiarism issues in academic writing.	J. de Foubert
3-4	Workshop 2: 'Brainstorming': Student presentation of thoughts on their research topic.	A. O'Dwyer
	Technical writing.	T. Burke
5	Workshop 3: Feedback of results of brainstorming session. Research methodologies.	A. O'Dwyer
6	Review Week	
7	*Research proposal planner submission (on WebCourses). 10% of mark.*	A. O'Dwyer
	Critical thinking, CoRT (Cognitive Research Trust) thinking techniques.	D. Gordon
8	Workshop 4. Small group brainstorming regarding proposal ideas and progress to date (including literature review).	A. O'Dwyer
9	The funding process, sources of funding, how to apply for funding, how to manage a funded project, IP, patents.	M. Rebow
10-13	*Student presentations on research proposal. Peer and tutor marking. 20% of mark.*	A. O'Dwyer
	Week 16: Submit 2000 word research proposal report (on Webcourses). 70% of mark.	Team

Table 2 Learning schedule for module: 2009-10.

Academic responsibility for the module was devolved to the author. The final research proposal report was shortened to 2000 words, partly because of the larger student numbers, but also because it was considered that report quality and length were not necessarily linked. Assessment was spread more evenly through the module, and the assessment strategy was refined. Firstly, a two-page research proposal planner, which provided a framework to develop and refine the research proposal, was submitted by students in Week 7; the proposal planner template was provided to the students in Week 1. This was followed by peer and tutor assessment based on short individual student presentations, scheduled over four weeks towards the end of the module. The author has significant experience of managing peer assessment (O'Dwyer, 2010), and this is discussed further in Section 4. All assessment criteria were detailed, and involved student consultation in their development; as an example, the assessment criteria for the research proposal report are given in Table 3.

	1+	1	2(1)	2(2)	P	F	
Introduction developed							Introduction not developed
Literature reviewed [1]							Literature not reviewed
Research questions identified [2]							Research questions not identified
Research methodology clear [3]							Research methodology unclear
Significance of study established [4]							Significance of study not established

Table 3 Assessment criteria for the research proposal report. [5]

Overall, the production of a research proposal planner was beneficial to the quality of the research proposal report. Figure 1 shows that there is a statistically significant positive linear relationship between the assessment results (for each student) for the research proposal report and the research proposal planner ($p = 0.0079$). In this data, $n = 54$ as five students taking the module decided not to submit a proposal planner. The research proposal planner was assessed wholly by the author; complete assessment time was approximately 8 hours, or approximately 9 minutes per research proposal.

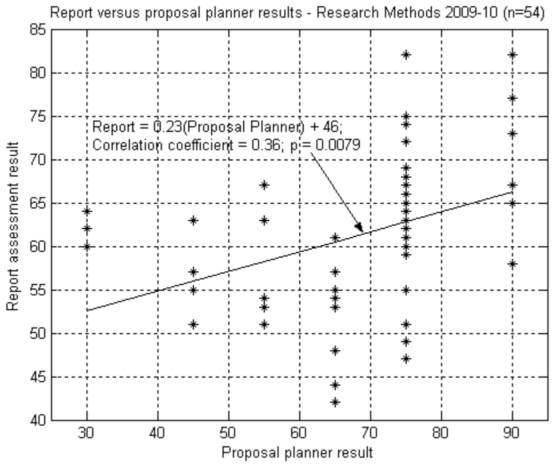

Figure 1 Relationship between report and planner assessment results

[1] Includes, as relevant, if the theoretical framework established/not established, if references are/are not to standard expected.
[2] Includes, as relevant, if the purpose of the study is clear/unclear, hypothesis developed/not developed.
[3] Includes, as relevant, if the research design is established/not established, if sampling issues are clear/unclear, if instruments are established/not established, if data collection issues are clear/unclear, if data analysis issues are clear/unclear.
[4] Includes, as relevant, if limitations have been considered/not considered, if ethical issues have been considered/not considered, if IP/patenting issues have been considered/not considered.
[5] A tick in the extreme left hand box means that the statement on the left is true and is of 1+ (90%) quality. The boxes from left to right are abbreviated by 1+ (90% - outstanding), 1 (75% - very good), 2(1) (65% - good), 2(2) (55% - adequate), P (for Pass – 45% - poor) and F (for Fail – 30% - very poor). In addition, space was provided for assessors comments.

4. PEER ASSESSMENT

A significant literature exists on peer assessment issues. For example, Falchikov (1995) provides an interesting and comprehensive literature review on peer assessment issues; other authors (e.g. Magin and Helmore, 2001) focus on the validity of peer and tutor assessment of the oral presentations skills of (engineering) students. Some authors give more specific advice on how to structure the peer assessment process (e.g. Falchikov, 1986), suggesting that the provision of explicit assessment criteria to the peer assessors is important. The contribution closest to the approach adopted in the Research Methods module (both from an assessment methodology and presentation procedure) is that of MacAlpine (1999).

The use of peer assessment (in this case of student oral presentations) is recognised as enhancing student communication skills and further develops student ability to work effectively, particularly as individuals. More generally, the method is learner-centered, motivates independent learning, caters to a diverse student background, raises awareness of ethics, unlocks student work and learning experiences to the benefit of all learners and provides case-study material that may be used on other programmes (O'Dwyer, 2010). The assessment template developed, after consultation with the students, has two parts: a 'presentation' part, and a 'contribution' part. The template provided to the students is now given; the presentation part is peer and tutor assessed, and the contribution part is tutor assessed only.

<u>Presentation [maximum assessment mark: 72]</u>
Content and presentation are assessed, following the structured guideline below. You are asked to 'tick' the appropriate box. A tick in the extreme left hand box means that the statement on the left is true and is of 1+ (90%) quality. The boxes from left to right are abbreviated by 1+ (90% - outstanding), 1 (75% - very good), 2(1) (65% - good), 2(2) (55% - adequate), P (for Pass – 45% - poor) and F (for Fail – 30% - very poor).

	1+	1	2(1)	2(2)	P	F	
Content	//						**Content**
Research question(s) identified							Research question(s) not identified
Literature review developed							Literature review not developed
Research methodology clear							Research methodology unclear
Accurate presentation of factors							Much questionable/inaccurate issues
Significance of study established							Significance of study not established
Presentation	//						**Presentation**
Attention-grabbing introduction							Uninspiring introduction
Convincingly argued							Argument lacks credibility
Clear and effective use of PowerPoint (inc. figures/tables)							PowerPoint use unclear and ineffective
Reasonable length							Too long/short
Animated tone							Flat or stilted or nervous tone

<u>Contribution [maximum assessment mark: 28]</u>
You can make brief helpful contributions and feedback about the presentation of each person. Each helpful contribution will receive either 1 or 2 marks (as a broad guide, 2 marks will be awarded for helpful feedback about the project content). Since there are 14 people presenting (excluding yourself), you can score a maximum of 28 marks from this part of the assessment.

Overall, Figure 2 shows a statistically significant positive linear relationship between the assessment results (for each student) for the research proposal report and the presentation ($p = 0.0109$). Other work shows that there is an average increase in the module mark for persons who collected their peer assessment feedback (collection was voluntary), suggesting that such peer feedback adds value to subsequent student work. The collation of assessment results was done wholly by the author and took approximately 25 hours or approximately 25 minutes per presentation.

Finally, the author requested student feedback, though a questionnaire, on the peer learning and assessment experience. Though the response rate to the questionnaire was disappointing, some excellent feedback was obtained. This will be discussed further at the conference.

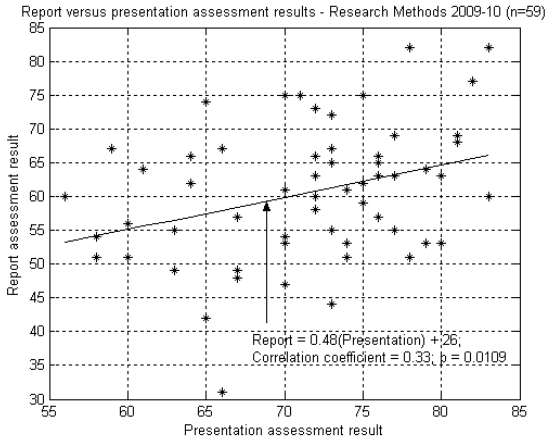

Figure 2 Relationship between report and presentation assessment results

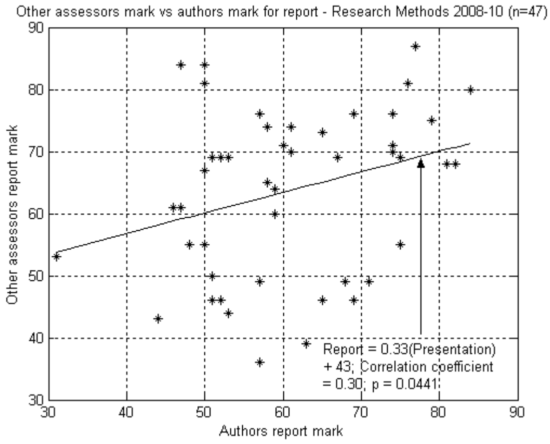

Figure 3 Relationship between other assessors report mark and authors report mark

5. REFLECTION ON MODULE

5.1 Assessment of research proposal reports

The research proposal reports prepared by students on the Pharmaceutical Process Control and Automation stream, and the Sustainable Electrical Energy Systems stream, were assessed by the author and one of three other assessors, in both academic years, using the assessment criteria detailed in Table 3. Figure 3 shows that there is a borderline statistically significant positive linear relationship between the other assessors mark and the authors mark for each student ($p = 0.0441$). This suggests that the assessment criteria may need to be more transparent. The assessment of the proposals, which take approximately 30 minutes each, is time consuming; however, the author recommends that, resources permitting, proposals should continue to be marked by at least two assessors, and that this assessment regime should also apply to proposals developed by students on the Mechanical Engineering stream.

5.2 Student feedback on the module

At DIT, student feedback on a module is obtained using a standard student survey questionnaire, in which students are asked to answer 32 questions, on a 4-point Likert scale, by ticking boxes, followed by a 'General evaluation and suggestions' section, which requests feedback on the good features and weaknesses of the module, and suggestions for module improvement. Student feedback was requested by e-mail. Though the response rate to the questionnaire was disappointing (at 36%), many interesting comments were made. An issue that exercised some of the students who completed the feedback was the difficulty they experienced in proposing and developing a research topic. One comment, from a student on the Pharmaceutical Process Control and Automation stream, is revealing: *Asking me what project I intend to do at the beginning of a course of study is pointless; I would have liked some guidance on a suitable project (or a methodology for finding one). Spending a considerable amount of time writing a research proposal on an idea that probably will not be pursued is a waste of time. I wanted this module to help me define a useful research topic, and how to carry it out. It may have achieved something with respect to carrying out a research project, but it completely failed to assist me in defining an area of research, which is for me a far greater difficulty*. As mentioned in Section 1, the Research Methods module was run in Semester 1 to prepare students for the engineering project which could start in Semester 2 for full-time students. None of the nine full-time students on the Pharmaceutical Process Control and Automation stream subsequently started the engineering project in Semester 2, though twelve of the seventeen full-time students on the Sustainable Electrical Energy stream did so. The course team concluded that more support is needed to help students, particularly on the former stream, to identify a research topic. In the future, an early meeting between all research active staff and students will be organised, perhaps on a 'speed dating' model, to allow the seeding of research ideas to occur.

5.3 Other reflections

- The first workshop will be modified to discuss the purpose of the module in more detail, in response to some student suggestions that this was not sufficiently clear.
- Though peer assessment is broadly supported by students who gave feedback, it is proposed to make more explicit the elements that are being examined in the 'Content' section of the peer assessment form. It is also proposed to examine the use of audience response systems ('clickers') to automate part of this assessment.
- Student feedback will be obtained in the classroom in future to maximise participation.
- Many students did not include a project schedule chart or treat intellectual property issues sufficiently in their research proposal reports. More generally, many project proposals were too ambitious for the project timescale. These pitfalls will be discussed in more detail the next time the module runs.
- Finally, though the author used Webcourses to store all resource material for the module, and for submission of assignments, students only used the platform for 5.5 hours, on average. The author is currently exploring the use of a wiki, on an MSc programme, as a collaborative learning tool to assist in the development of individual student research proposals; experiences gained will inform further developments for the Research Methods module on the ME programme.

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A STRATEGY FOR TEACHING SUSTAINABILITY ASSESSMENT

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Abstract: Educating engineers to be active in sustainable development is by no means a trivial task and the challenge has been pursued by several universities and organisations around the world. At DTU MAN research and teaching is focused on engineering management tools. In the section for Quantitative Sustainability Assessment (QSA) the research and teaching is embedded in Life Cycle Assessment (LCA) and Life Cycle Management (LCM) tools. Our vision is that all engineers graduating from DTU are taught a basic knowledge about sustainability and the methods and tools to assess the sustainability of their decisions. Our strategy for the teaching address three target groups and follows two routes.

- One route provides in-depth education for students aiming to specialise in quantitative sustainability assessment. A variety of courses ranging from production level through company level to society level will be offered.
- The second route aims to present concepts of sustainability and potential impacts of the specific technology field as well as methods and tools for specific domains, i.e. nano technology. It is targeted two groups of students at the different technological domains at DTU; those specifically working in innovation and technology development and engineers developing solutions based on existing technologies. The DTU curricula will integrate sustainability assessment in introductory courses at bachelor level, whereas master level courses goes more in detail with the specific sustainability issues for that technology domain and introduces quantitative tools to assess sustainability.

The proposed strategy embeds sustainability throughout the engineering curriculum.

Keywords; Sustainability assessment tools, engineering education, bachelor, master, POPBL

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1. INTRODUCTION

1.1 Sustainability in engineering education

Addressing the presently unsustainable development of the global society, engineering is seen as a part of the problem as well as a part of the solution. Engineers seek to apply the knowledge of science to deliver practical solutions and have to a large extent contributed to the technology development that led us to the current state. However, engineers are also a key to the solution and they need to recognise the context in which the solution is required. The 2002 World Summit on Sustainable Development (WSSD) emphasized the educational objectives of the Millennium Development Goals and proposed the Decade of Education for Sustainable

Development for the period 2005–2014 with UNESCO as the leading agency (Uwasu et al. 2009). In Europe a more recent document targeting the engineering education for sustainable development is the Barcelona declaration from 2004 (Segalas et al. 2009). Additionally also the Royal Academy of Engineering in the UK have published their guiding principles for engineering for sustainable development (Royal Academy of Engineering 2005).

Sustainability has found its way into curricula of many engineering educations around the world ((Perdan et al. 2000, Fenner et al. 2005, Allenby et al. 2009, Onuki and Mino 2009, Quinn et al. 2009, Segalas et al. 2009, Uwasu et al. 2009). A questionnaire survey in the U.S.demonstrated clear evidence that teaching and research in sustainable engineering forms part of the activities of the top 100 engineering programs in the U.S. (Murphy et al. 2009). In the Netherlands, the board of Delft University of Technology adopted an educational plan in 1998 encompassing three interconnected operations aiming at teaching sustainability to all engineers (Peet et al. 2004). In Sweden, the Swedish law for higher education has, since February 2006, included a requirement that all higher education should contribute to promoting sustainable development. Chalmers University of Technology has chosen to strive for an integration of sustainable development into all engineering programmes. Actually, a policy at Chalmers created already in 1985 require that the bachelor curriculum in all engineering programmes should contain compulsory courses of 7.5 ECTS-points[1] concerning environment and sustainable development (Segalas et al. 2009). In Japan an initiative called IR3S (Integrated Research System for Sustainability Science) led by University of Tokyo with Hokkaido University, Kyoto University, Ibaraki University, and Osaka University as the participating universities, have the mission to establish sustainability science by promoting activities in three fields; research, education, and cooperation with industries (Uwasu et al. 2009). The Norwegian University of Science and Technology (NTNU) was very early in offering an education in “industrial ecology” in the mid 1990’s. A number of other NTNU programmes incorporate environmental issues early on as part of their educational offerings. These courses of study offer specializations that are related to sustainable development (NTNU, 2010). The importance of education in sustainability, especially for engineers, is illustrated by the emphasis on this topic around the world.

1.2 Sustainability at Technical University of Denmark (DTU)

DTU have app. 6000 students most of which aim at a master level degree in engineering. At DTU sustainability is embedded implicitly in the teaching strategy, but there is no direct reference to or adoption of a sustainability agenda. It is stated that students must have ”a comprehensive polytechnic approach” which in a more recent interpretation must include sustainability. The research strategy has direct reference to sustainability:”DTU will promote promising fields of research within the technical and the natural sciences, especially based on usefulness to society, relevance to business and sustainability”.

An illustration of the sustainability oriented education activities at DTU is the “groen dyst” (green competition, www.groendyst.dtu.dk) program in June 2010. All engineering student at

[1] ECTS (European Credit Transfer System) describes the workload of a course. 60 ECTS points corresponds to 1 year of full time studies ≈ 1500 hours of student work

DTU have been personally encouraged to enroll with a project (5 ECTS-point) that have a sustainability perspective and to participate in the final conference and competition.

At the QSA (Quantitative Sustainability Assessment) section at DTU MAN we focus our research and teaching on quantitative methods for sustainability assessment and implementation of these. The more qualitative or socio-technical aspects are addressed by other sections at the department. Focus for the remainder of the paper will be on the activities of the QSA section even though activities in sustainability are also on-going in e.g. civil engineering.

2. TEACHING STRATEGY

2.1 Mission and vision

The mission of the QSA section is “To offer education in sustainability assessment methods and tools to all engineer students at DTU. Partly as obligatory parts of introductory courses at all bachelor study lines, partly as electives at all master study lines, and finally as a study line in itself.”

The vision of the QSA section is that:

- “All engineers graduating from DTU should be able to administer the sustainability dimension in business and society. They must know what sustainability is and how their decisions as engineers can affect sustainability. Further they should be aware that there are methods and tools to assess the sustainability of their decisions.
- All engineers graduating from DTU with a specialization in innovation and development of technology, systems or products should understand the principles of sustainability assessment and be able to apply tools for sustainability assessment.
- Engineers graduating from DTU should be able to specialize in tools for quantitative sustainability assessment of products, systems, and technologies.”

The QSA section strives to be the driving force in implementing the sustainability assessment in research, education and industry creating collaboration broadly at DTU, as well as nationally and internationally.

2.2 Strategy

The QSA section aims to disseminate the knowledge about sustainability assessment partly via teaching in our core area to specialists, and partly through introducing sustainability knowledge and tools to students in other technical fields at DTU. The teaching in sustainability assessment methods and tools thus has three legs targeting different groups of students, see figure 1:

- Teaching in methods and tools for sustainability assessment targeted at the different technological domains at DTU, providing a background knowledge to students pursuing a career in other technical fields

- More in depth education for students aiming to work with the development of technical solutions and therefore wishing a more in depth knowledge of the tools available to assess sustainability of technologies
- Specialized teaching and education in principles and methods for sustainability assessment targeted at the student pursuing a professional career within the field

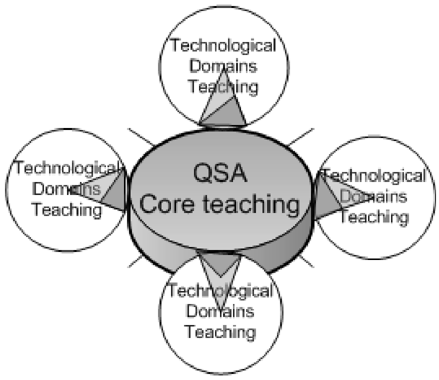

Figure 1: The QSA section's three legged strategy for education encompass education in QSA core competences for engineer specialists in the field and teaching to engineer students in other technical fields (basic knowledge (dark grey triangles) or for innovation and development (light grey triangles)).

This strategy is very much in line with the plans for education in sustainability adopted at Delft University of Technology and at Chalmers University of Technology although not adopted by the top level management at DTU. In Delft the plan encompasses three interconnected operations (Peet et al. 2004):

1. The design of an elementary course "Technology in sustainable development" for all students of DUT;
2. Development of graduation in sustainable development in each faculty and department; and
3. Intertwining of sustainable development in all regular disciplinary courses, in a way corresponding to the nature of each specific course.

Likewise, at Chalmers they are striving to integrate sustainable development into all engineering programs as well as teaching all bachelor students compulsory courses in sustainable development (Lundqvist and Svanstrom 2008, Segalas et al. 2009) the content of which is discussed more thoroughly in (Lundqvist and Svanstrom 2008).

The QSA teaching strategy at DTU aim at creating awareness of sustainability and assessment tools among the engineer students at every bachelor study line (currently 13 different study lines are offered, e.g. biotechnology and electro technology). One component of this is an introductory 5 ECTS point course in sustainability (and tools) which initially will be elective (bachelor degree requires 180 ECTS points of which 45 are elective). The other component involves introductory modules within technical courses at each bachelor study addressing specific sustainability issues. The teaching should be placed early in the study. Every master study line should offer courses including elements of sustainability assessment either in the electives or in the compulsory courses. Furthermore, a range of courses specializing in sustainability assessment and management will be offered as electives, see also figure 2.

Taking into account that there are 13 bachelor study lines and even more specializations at the master level it can become a huge task if the QSA section is to be responsible for all education in sustainability. The educational plan at Delft University of Technology (educating app. 6 times more students than DTU) address this issue by stating that sustainable development should be integrated into all regular disciplines, i.e. integrating education in sustainable development into core technological/scientific courses. There are quite a few barriers to this approach as described in Peet et al. (2004). One is e.g. a resistance to change curricula because of an already tight programme leaving little space for topics that are not core to the specific subject. “Interdisciplinary work is perceived as important only for applied projects, not for scientific progress as it does not contribute to the conceptual core of the discipline. This creates a barrier for the introduction of sustainable development in the academy, since sustainable development is inherently multidisciplinary” (Peet et al. 2004). Acknowledging such barriers a fully fledged version of our strategy will require adoption and commitment from the top management of DTU before researchers and lecturers from other departments will get involved.

3. TEACHING ACTIVITIES

3.1 Courses offered

At the QSA section we offer a number of courses as illustrated in figure 2, where also courses that are planned are included. As illustrated, emphasis is put on covering all three pillars of sustainability (prosperity, people, and planet). Although our point of origin has been in the environmental life cycle assessment our staff now also covers the social aspects, whereas the economic aspects still depends on cooperation with other institutions.

Each faculty staff will, in addition to their specific expertise, be responsible for the collaboration with one or more technological domains at DTU and for initiating teaching offered at the respective bachelor and master study lines. A typical distribution of teaching for each staff would be 2/3 in specialized courses and 1/3 at other technological domains. The teaching at technological domains should cover more in depth the specific issues relating to that domain, e.g. how much do the specific technologies contribute to sustainability impacts, what activities are most relevant in relation to sustainability (is it the production or the use stage for example, or is it energy consumption or release of toxic chemicals?) in order for the student to better relate the sustainability aspects to the specificities of their own study. At bachelor level one or two modules (4-hour modules) at the first or second semester as well as the elective 5 ECTS point course would be anticipated.

We have successfully been involved in the 1. semester introductory course for manufacturing engineers with 2 modules illustrating the importance of taking in a life cycle perspective in development of products and technologies through teaching a module on sustainability followed by introduction to a simple assessment tool with hands-on experience by the students.

At the master level, cooperation with the civil engineering department has just started and 4 modules are taught by QSA staff at a course on optimization, resources and environment.

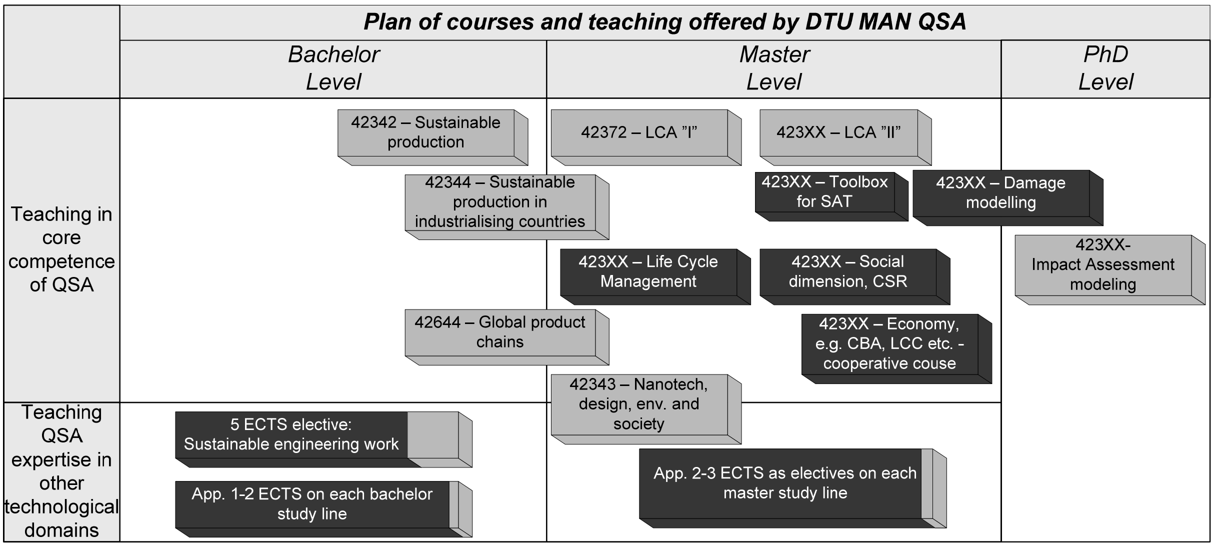

Figure 2: Overview of courses offered (light gray also those with concrete plans) and planned (dark grey) from the QSA section. The succession of the courses is not entirely illustrated and will depend on the interests of the students although there are a few courses that are obligatory in order to proceed with other courses (e.g "LCA I" is obligatory for "LCA II"). The sizes of the boxes do not correspond to the content/size of the course (ECTS points).

A course which has been running for 3 years with a total of app. 30 students is the course "Nanotechnology, design, society and environment" which is based on the sustainability assessment methodology presented in Olsen and Jørgensen (2006). Although not directly in cooperation with researcher from physics and nanotechnology, they have given lectures on the course which has also been followed by a total of app. 10 students from Physics and nanotechnology.

The pedagogical approach in all QSA courses (although not necessarily in single modules in other courses) is problem oriented and project based learning (POPBL). Theory lectures are combined with case based projects and evaluations of the students is by individual assignments as well as by the team based project reports. For example the course on Life Cycle Assessment, which is a 10 ECTS point course followed by app. 50 students per year, has since the course started in the mid 1990's encompassed a case project running throughout the course where the student have worked on a concrete problem for a company.

3.2 Introductory course in sustainability

As previously mentioned an introductory course of 5 ECTS points which is intended to be followed by students from all bachelor study lines is currently being developed. Similar courses are already running at e.g. University of Limerick (Quinn et al. 2009), Delft University of Techology (Peet et al., 2004) and University of Windsor (Tam 2007) (although a post graduate course). The approach taken by Chalmers University of Technology differs a little since the courses may differ between different study lines (Lundqvist and Svanstrom 2008).

Again we aim to use POPBL taking departure in problems the students find interesting. In this learning by doing approach the students are presented to tools e.g. ecological footprint, simplified life cycle assessment, DfE, CSR-kompass, and CBA. Applying these tools they observe how different choices can influence the sustainability of their solutions. Theory and context will be presented along the course after the students have identified issues they need to learn to understand the sustainability context. A preliminary list of topics is shown in table 2 together with the learning outcomes.

Theories and concepts covered	Learning outcomes (the student will be able to)
• Absolute sustainability vs. relative sustainability • Life cycle perspectives and Cradle-to-Cradle concept • DPSIR (Driving forces – Pressures – Stressors – Impacts – Responses) • Consumer behaviour • Environmental regulation • Actor network analysis • Governance (e.g. actors in sustainability, Marrakesh process etc. WBCSD) • Change management	• Describe the three pillars of sustainability (BT – 1) • Explain that every dimension is multifactorial and that trade-offs exists within and between them (BT-2) • Illustrate how companies can work towards development of sustainable solutions (BT-2) • Describe the product chain perspective (BT-2) • Know and apply different simple tools for sustainability assessment (BT-3) • Explain that assessments involve integrated sensitivity analysis and iterations (BT-2) • Relate critically to the results of the different assessment tools (BT-6) • Master analysis of solution by means of simplified LCA (BT-4) • Master synthesis of solution by ecodesign principles (BT-5)

Table 1: Topics and learning outcomes (Bloom's taxonomy (BT) for cognitive learning (1-Knowledge, 2-Comprehension, 3-Application, 4-Analysis, 5-synthesis and 6-Evaluation))

Overall it is the aim that the students will acquire an understanding of the concept sustainability and the three dimensions of sustainability. They will get an overview of a range of methods and tools for analysis and synthesis of solutions that are sustainable in their whole life cycle and acquire the skills to operate them. And finally they will get an understanding of the engineer's role and responsibility in a sustainable society.

4. CONCLUSION

A teaching strategy for the QSA section at DTU MAN has been presented that is very much in line with the general trends in engineering education in sustainability. Some plans for education are more official being adopted by top management of the universities but nevertheless meets barriers in terms of organizational, academic and engineering culture. These are hurdles that have to be met proactively in the further development and implementation of the teaching strategy

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REMOTE FREE FALL EXPERIMENT FOR DYNAMIC STUDIES

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Abstract: Within the strategy of Integrated e-Learning (INTe-L) in the discipline of mechanics we set up a set of remote interactive mechanics experiments across the Internet. A new and sophisticated experiment, free fall for instantaneous position, velocity and acceleration determination, has been constructed (http://remotelab4.truni.sk) based on the movement of a permanent magnet in a glass tube with induction pick up coils for position measurement. To transform the hands-on experiment into a remote one, we have had to move the magnets to their starting position by the magnetic vessel, surrounding the tube. The experiment was used with success for the study of the basis of mechanics and for verifying Faradays' law.

Keywords; free fall, Internet School Experimental System (ISES), Integrated e-Learning (INTe-L), remote Internet experiments.

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1. INTRODUCTION

The development of information communication technologies has made it possible to introduce remote experimentation as an indispensable and missing part of e-Learning. We proposed and realized the new technology of education - Integrated e-Learning (INTe-L) (Schauer 2008a, 2009). INTe-L is a new strategy of physics education based on the method sciences use for the cognition of the real world, starting from experiments. In this respect remote experiments will play a decisive role as described by Cooper (Cooper 2005). The teaching of mechanics is usually a starting point of any basic university physics course, where the support of experiments is decisive and remote experiments are generally missing. The reason is the difficulty in the technical implementation of any mechanical experiments, in the necessity to build the PC controlled actuators that are far beyond the abilities of most university educators. Here, potentially, remote experimentation may help, and we hope for a future network of remote experimentation, created and shared by interested universities (Ožvoldová, 2009).

In this article we take one step in the right direction and exploit the possibilities of remote experiments in mechanics. We chose two experiments: First, free fall in a tube, an experiment in the dynamic range of the fractions of seconds with the need of mechanical actuators for teaching Newtonian mechanics and conservative and dissipative forces (this paper); Second, reconstructing the instantaneous deflection angle of a pendulum for teaching kinematics, dynamics and energetics of oscillatory motion (this conference Schauer).

2. EXPERIMENT FREE FALL OF A BODY

2.1 Hands-on experiment Free fall

A free fall experiment in a tube is a popular experiment. Based on the motion of a permanent magnet in a tube inducing electromotive force in the coils distributed along the tube and giving corresponding signals, it is one of the most frequently used experiments on free fall (Kingman, 2002). It is used in many modifications from a simple recording of the signal to the most sophisticated applications such as the fall in conductive media, where the motion may give surprising information for students on the tube conductivity. We built the PC based experiment on the system ISES (Internet School Experimental System (Schauer, 2008b), enabling both hw solutions (tube with coils ISES, signal V-meter module ISES) and sw support (signal recording and data smoothing, processing - recording of chosen typical data, fitting, etc).

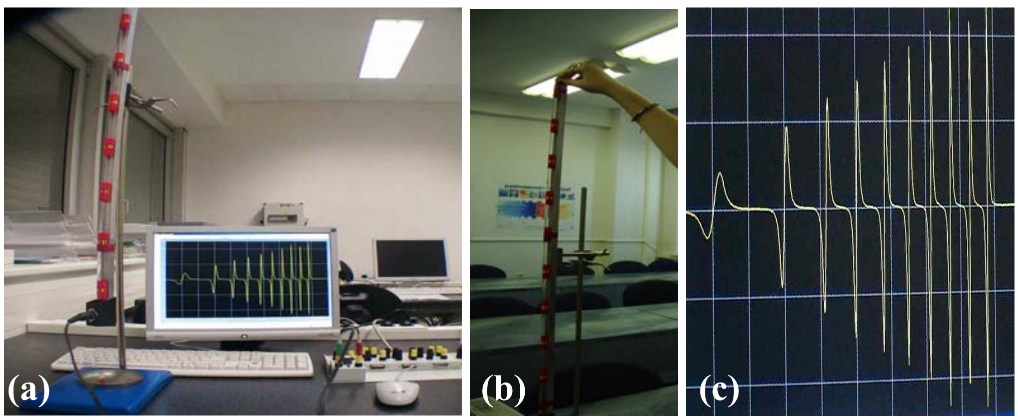

Figure 1 a) Arrangement of the experiment Free fall, b) manual start of a magnet, c) a typical signal of the free fall in the air recorded by the ISES system.

In Figure 1 is the hands-on experiment used in the laboratory exercises with the data processing and evaluation: a - arrangement of the experiment, b - start of a free fall, c - a typical recorded signal in air. You can see in Figure 2a the magnetic flux $\Phi(t)$ of a falling magnet (up) and corresponding time dependences of the electromotive voltage $U(t)$ (down), and in Figure 2b is a typical signal in a liquid.

The experiment was performed successfully in both mechanics (Ožvoldová, 2009) and as a Faraday law experiment in an electromagnetic theory course (Schauer, 2008a).

When we started the transformation of the hands-on experiment to the remote one, the detailed evaluation of the data of the experiment systematically produced differences between the results of other experiments on the free fall and the free fall in a tube, caused by the presence of dissipative forces. We decided to introduce these dissipative forces during the experiment artificially, and then control and measure them. The tube enables us to both eliminate and enhance the friction forces in a controlled manner, changing the density of the gas in the tube.

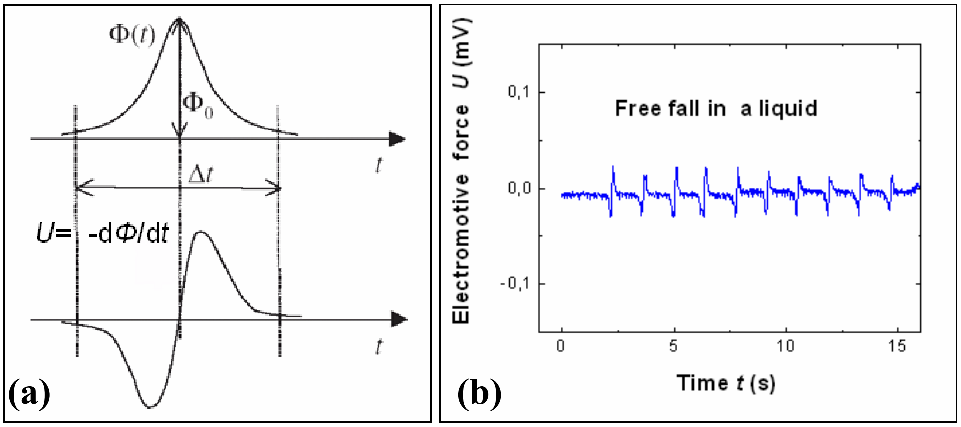

Figure 2 a) The magnetic flux $\Phi(t)$ of a falling magnet in a coil (up) and electromotive voltage $U(t)$ time dependences (down); b) A typical signal in a liquid.

This is accomplished by both the rotary pump and controlled gas pressurizing of the tube. In the future the liquids introduced to the tube may serve for experimentation in viscous media. The theory of the free fall in dissipative media is starting from the differential equation (assuming the positive direction for y is chosen to be upward) with the general solution for the motion in low pressure gasses (neglecting the buoyancy force)

$$m\frac{\mathrm{d}^2 y}{\mathrm{d}t^2} = mg - \mathrm{k}_1 v \qquad \Rightarrow \qquad v(t) = \frac{mg}{\mathrm{k}_1}\left(1 - \mathrm{e}^{-\frac{k_1 t}{m}}\right) \tag{1}$$

and for the motion in viscose liquids

$$m\frac{\mathrm{d}^2 y}{\mathrm{d}t^2} = mg - \mathrm{k}_2 v^2 \quad \Rightarrow \quad v(t) = -\sqrt{\frac{k_2}{mg}}\,\mathrm{tgh}\left(\frac{\mathrm{k}_2 g}{m} t\right) \tag{2}$$

where m is the falling body mass, t is the time and v is the velocity, k_1 and k_2 are the corresponding coefficients of dynamical friction. The numerical solutions for arbitrarily chosen parameters k_1 and k_2 give displacement–time and velocity-time dependences in Figure 3a, b.

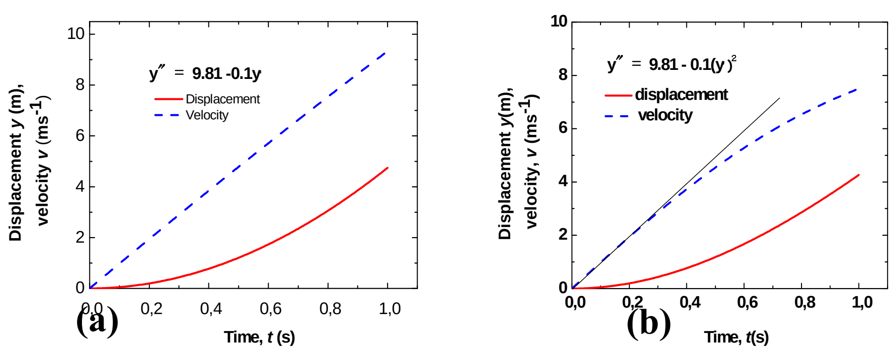

Figure 3 The modelling results of the time dependencies of the displacement y (t) and velocity v (t) - a) (eq. 1) ; b) (eq. 2).

2.2 Technical means of remote experiments

The basis of all our solutions for hands-on experiments is the system Internet School Experimental system (ISES) described elsewhere in detail (Schauer, 2008c). It consists of sw and hw solutions for a wide range of experiments in physics, chemistry and biology. It offers about 40 modules of sensors and outputs of typical analogue signals, program for data recording, storing and processing. The recent component part of the ISES system is the WEB CONTROL kit for easy building of the remote experiment, a detailed description of which can be found elsewhere (Schauer, 2009). It enables the easy construction of remote experiments on the basis of ISES hw by inserting the pre-prepared building blocks into the html programme, formed by the compiled Java applets for typical controls and graphs, and setting their parameters.

2.3 Remote experiment Free fall

Once the computer-based experiment using the ISES system is built, a second step in establishing the remote experiment is needed, i.e. the establishing of the classical server-client connection with data transfer from the server to the client and in the reverse direction for the control of the experiment by the client (experimenter). For this purpose, we built the software kit ISES WEB Control (Schauer, 2008b) for the easy transformation of the computer- oriented experiment.

To transform the hands-on experiment to the remote one, the most demanding task was to repeatedly lift magnets to their starting position. For this purpose we devised and used the electromagnetic vessel, depicted in Figure 4b (down), lifted by the screw driven by the step motor (Figure 4b (up)).

To plan and programme the experiment, a detailed time and logic scheme of experiment is needed, serving for the proper functioning of the experiment. For this purpose a standard flow chart serves nicely, resulting in the corresponding programme and the chart of the experiment in Figure 4c http://remotelab4.truni.sk (Ožvoldová, 2009).

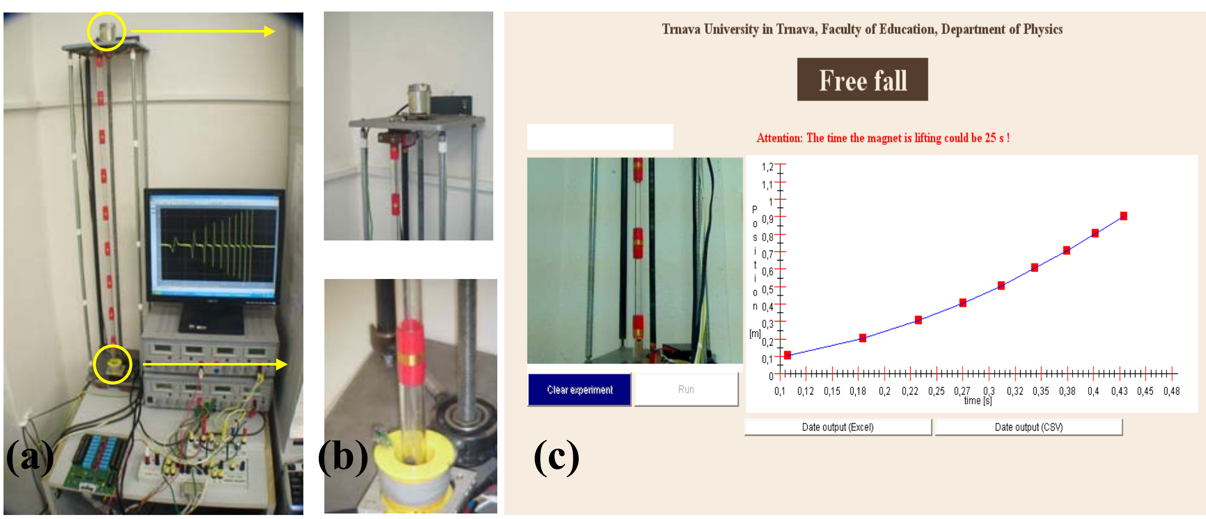

Figure 4 The remote experiment free fall - a) the total arrangement, b) details: the magnetic vessel lifted by the screw (down), the step motor driving the screw (up), c) the www page of the remote experiment free fall with life camera view and instantaneous position time graph dependence.

3. CONCLUSIONS WITH IMPLICATIONS FOR INTE-L

The main conclusions of the remote experiment free fall may be formulated as follows:

1. The remote experiment from mechanics with mechanical actuators was devised and successfully implemented.
2. The fast dynamic range in the fraction of a second for the whole experiment with the transfer rate across the Internet with 100 kHz sampling rate was successfully mastered.
3. The dissipative forces were introduced into the experiment by the variable gas pressure from vacuum-like conditions to increase pressure above the atmospheric conditions. We intend to introduce liquids to test the motion in strongly viscous media.
4. The technical and financial requirements to build such experiments call for the establishing of a European university network of remote experiments, covering a basic course of physics based on nearly identical syllabi.

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INTRODUCTION OF THE PROBLEM BASED LEARNING TO MECHANICAL ENGINEERING CURRICULA

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Abstract: Although the technical learning has a long and successful tradition in Brno, new trends must be accepted to cope with the needs of modern industrial demands. From the communication with our industrial partners and graduates we registered serious drawbacks of contemporary educational system leading to low competency of our students. To cope with this situation, an innovation of curricula in engineering areas of Applied computer science, Mechatronics, Engineering design, Robotics and Engineering mechanics and biomechanics is prepared. The key point of the innovation is the introduction of Problem Based Learning (PBL) into the above mentioned subjects. Main idea of PBL is shifting the educational process from the „learning by hearing“ to the „learning by doing“ mode. In the paper we describe our experience with PBL introduction as a part of a running project funded by the European Social Fund.

Keywords; engineering education, problem-based learning.

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1. INTRODUCTION

Faculty of Mechanical Engineering (FME) is the second largest one of the Brno University of Technology, having about 4400 students and 500 employees in 14 specialized institutes. It provides structured education (3 years Bachelor`s, 2 years follow-up Master`s and 4 years doctoral studies) in 50 study programs in both full-time and combined modes of study. All of the study programs are accredited in Czech and English, and there are joint and double degree programs in cooperation with other European universities. The university is a holder of European Credit Transfer System and Diploma Supplement Label.

FME provides university education in traditional mechanical engineering areas as well as in interdisciplinary branches, some of them in close cooperation with other BUT faculties and universities (Mechatronics, Mathematical Engineering, Physical Engineering and Nanotechnology, Precise Mechanics and Optics, etc.). Each year, about 750 students graduate from the faculty having good career prospects at both Czech and European labour markets. According to a survey that we realized at the faculty within our project, FME graduates are of those having no great problems to find a job (Fig.1). In spite of this successful performance, there are still serious drawbacks of contemporary teaching system, detected in discussions with our graduates and representatives of industrial companies. Criticism is aimed primary to lack of social skills, ability of team work, soft skills and leadership. To improve educational procedures in this specific area, we prepare curricula innovations with main accent on team work in small groups, problem solution and mutual evaluation of presented solutions among concurrent groups. One example of successful application of this learning strategy is the project of walking robot design with typical distribution of responsibility of team members to different aspects of the problem: kinematics and dynamics of movement, design of mechanical parts, power supply, servo-drives, electronics and intelligent control. Area for this learning strategy is found partly by revision of classical courses, partly by introduction of new courses like Industrial Project or Diploma Seminar. Introduction of the new learning strategy and problems with its evaluation and impact is the subject of a new ESF project, described in the following text.

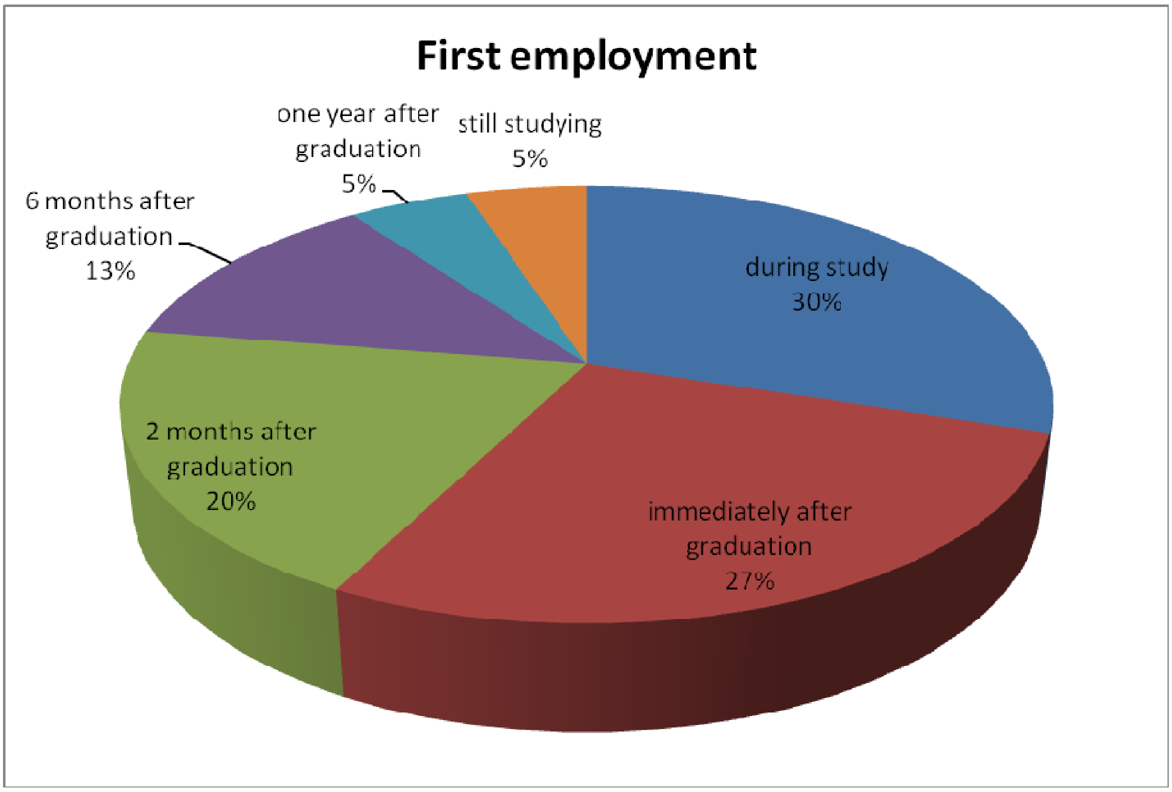

Figure 1 First employment of FME students

2. PROJECT DESCRIPTION

2.1 Drawbacks of the existing system

The system of technical education at the FME has been reflecting many changes, some of them come from the discussion with companies and the others as the feedback from the graduates. In general, graduates are well prepared in technical and theoretical areas, but the practical experience, social and language skills are of a great lack. Especially, the existing educational system leads to low competency of our graduates and students in areas like

- management ability

- adaptability and creativity
- communication, self-presentation, teamwork
- social, economical and juridical context of engineering activities.

Results of our survey in Fig.2 show what our graduates miss most when starting their professional careers.

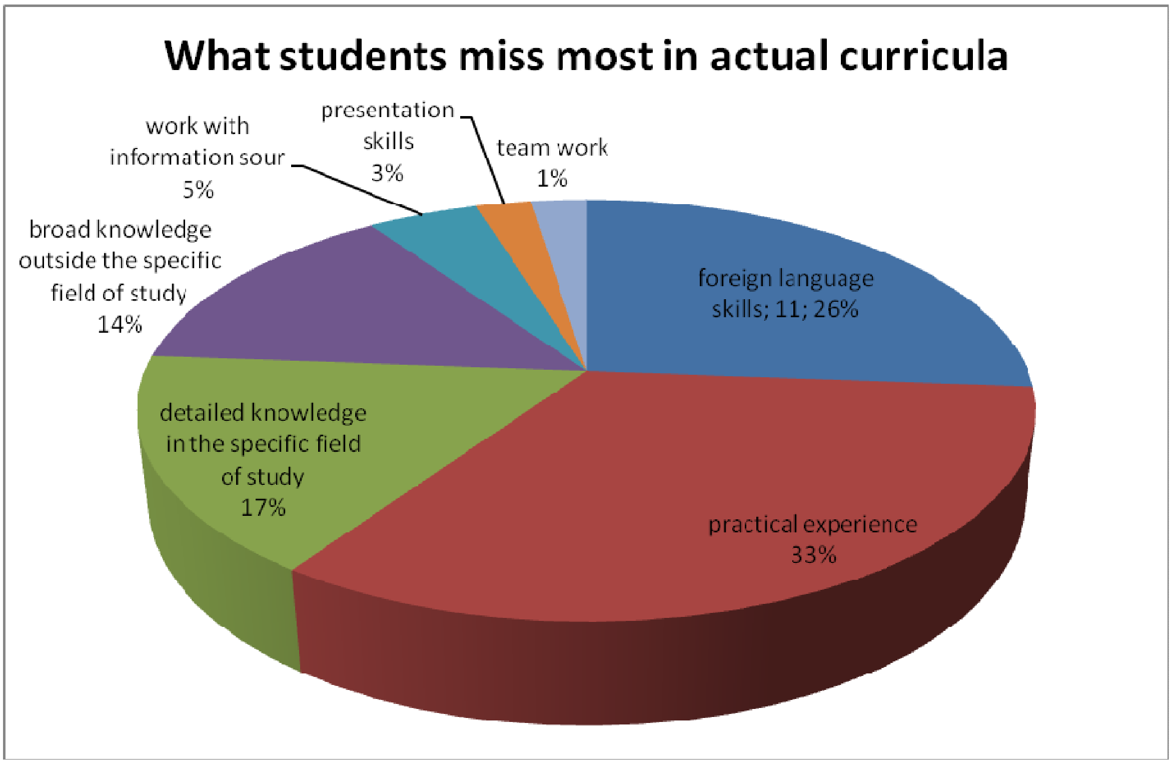

Figure 2 Results of survey among graduates

To cope with this situation, an innovation of curricula and educational methods in engineering areas of Applied computer science, Mechatronics, Engineering design, Robotics and Engineering mechanics and biomechanics is being prepared within the support of ESF project no. CZ.1.07/2.2.00/07.0406 "Introduction of the Problem Based Learning to Mechanical Engineering Curricula" (May 2009 – April 2012; http://opvk22.umt.fme.vutbr.cz/).

2.2 Project aims

The main idea of the project is shifting the educational process from the „learning by hearing" to the „learning by doing" mode, from isolation to openness, from separated to modules, from specific knowledge bulk to dealing with specific complex task (Brodeur et al.(2002), Lo (2007), Fink (2002), Hadim and Esche (2002)). The key point of the innovation is the introduction of Problem Based Learning (PBL) into as many subjects as possible, reasonable and effective in different ways for Bachelor`s and Master`s programs. Problem-Based Learning is a widespread teaching method in disciplines where students must learn to apply knowledge, not just acquire it.

The main goal of PBL is to provide students with opportunities to apply knowledge and is focuses on problem formulation as well on problem solving. The main features of the PBL are as follows:

- leaning is student centered (student makes a choice about how and what he wants to learn)
- learning occurs in small student groups and promotes collaborative learning
- teachers are guides or coaches
- a problem is a vehicle for the development of authentic problem-solving skills
- new information is acquired through self-directed learning.

To introduce the PBL into the educational process at the FME means that the learning process in engineering disciplines becomes more enjoyable and more efficient for students mainly through practical projects, provides team work and other soft skills experience and stimulates a student interest itself.

2.3 Project partners and key activities

There are several departments of two faculties being involved in the project – Institute of Solid Mechanics, Mechatronics and Biomechanics, Institute of Design, Institute of Computer Science, Institute of Production Machines, Systems and Robotics (all Faculty of Mechanical Engineering) and Institute of Power Electrical and Electronic Engineering (Faculty of Electrical Engineering and Communication).

The project consists of the following main parts – key activities:

1. analyses of the labor market (a survey among graduates and companies focused on skills missing) – the survey was realized among 132 graduates (2007-9) of study branches involved via emails
2. usage of external experience and comparison of similar study programs offering by partner universities – still ongoing process of monitoring of partnership faculties and their study programs offered (extension, content, courses, modules, learning methods and forms, possibilities of joint / double degree programs)
3. problem based module structure (a system of basic educational modules with defined processes, methods, structures and criteria and their use for other study branches)
4. formal and content changes of courses included (up to extension enabled by the accreditation of the Czech Ministry of Education) – new or innovated educational materials, different credit evaluation, implementation of the new trends and knowledge in research and technologies, instructive forms of education, team projects working out, opponency of the projects to support presentation and self-presentation skills and communication
5. complex electronic support and knowledge testing system – centralized and problem oriented portals including all the information on courses and study plans, knowledge on-line testing system, webcasting, database of problems and assignments, references
6. intensifying of practical experience in the educational process (in both university and company facilities) – upgrade and new equipment of laboratories, experimental tasks, software applications, excursions into companies, internships, part-time jobs, testing of companies products within training of students
7. realization and evaluation of new study plans.

The role of industrial partners (both Czech and international companies) in the project realization is irreplaceable. The companies (e.g. Siemens Electric Machines, ZDAS, Honeywell) are responsible for:

- providing practical experience by the means of short-time practices, students` excursions, diploma projects setting, consulting, experts` lectures, trainee programs
- offering jobs for our graduates (in rate between Bachelors` and Masters` graduates 15 to 85%)
- supporting our students (part-time job, scholarship, sponsorship, students competition, etc.).

2.4 Realization problems

At present, the project is in the first year of realization and four of the above mentioned key activities are being now solved. Some of the problems have already been identified:

- lack of teachers being qualified and interested in this educational method (especially when the teacher should be more manager or facilitator than expert in the subject area)
- too many students in Bachelor`s study programs in proportion to experienced teachers,
- reluctance to creative activities, teamwork and cooperation among some students in case when the study groups are too large
- insufficient language knowledge and soft skills
- lack of appropriate problems and practical tasks on different levels to deal with
- shortage of devices and equipment to be used for practical learning.

We cope with these problems by many ways. First, we are directed towards young colleagues-teachers who seem to be most interested in new teaching methods, are able to do the time-consuming work of new curricula preparation and are open to new partnership with the students. Lectures and seminars of experts outside the academic area are a great help for us (Fig.3). On the other hand, some method of selection among the students in the large groups of the undergraduate Bachelor`s study is necessary to find and motivate those who show necessary initiative and interest in the new forms of learning. The problem of laboratory equipment and devices is improved in last months (Fig.4) partly by the ESF Projects funding, partly by better exploitation of other sources (Czech Ministry of Education, commercial subjects participation).

Figure 3 Experts of Skoda-Auto in FME labs

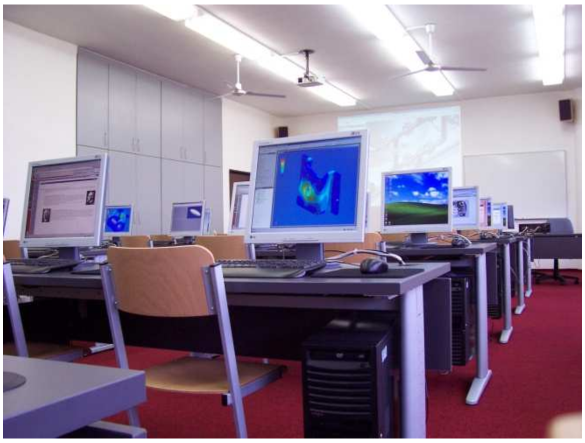

Figure 4 New computer labs

3. CONCLUSIONS

The first experience with the concept of Problem Based Learning in engineering education at the FME shows a necessity of deep change of traditional role of the teacher as an instructing authority, student as a passive object and the education as a pre-fabricated process with a small proportion of individual creative contribution on both sides. It will be a long-termed and complicated process. We believe that the whole process brings expected results, which can be judged only after a longer period of exploitation of the project outcomes and their evaluation by graduates and employers.

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INVESTMENTS IN EDUCATION DEVELOPMENT

SOME FINNISH VISIONS OF ENGINEERING EDUCATION

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Abstract: The Finnish higher education system consists of two sectors: universities and universities of applied sciences. The latter are also called polytechnics. Both sectors have significant engineering education.

The engineering education is not very popular in Finland nowadays. This causes problems in the future.

There are some Finnish Visions:

A) The National Cooperation Group for Engineering Education was set up in 2007 in order to produce a national strategy for engineering education in Finland. The group has members from the Ministry of Education, universities, unions and labour market. The Group submitted its interim report "Well-being from Technology through Cooperation" in January 2008.

B) The mission of the Finnish engineering education is to benefit people and the environment through providing knowledge and skills, research and innovations for the society and business life. As part of the National Strategy Project for the Engineering Education it was seen necessary to find out what kind of learning objectives do the challenges associated with sustainable development impose on the Finnish engineering education and how have the units providing engineering education responded to these challenges. Therefore, a research study was conducted at the Finnish Association of Graduate Engineers TEK.

C) The Ministry of Education and all Finnish universities of applied sciences have a project called ENGIN. The project goals are
(1) to increase the attractiveness of engineering studies,
(2) to shorten the studying time and
(3) to decrease the number of interruptions of the studies.
The project contains three groups: the group of structure development, the group of marketing and the group of teaching methods. The project has already organized some seminars and published two books about good learning practices.

Keywords: engineering education, vision, national strategy, sustainable development

1. INTRODUCTION

The engineering education is very significant to the Finnish economy. Engineers solve many problems and overcome challenges of today and tomorrow. But the opinion of the youth about engineering studies is nowadays not very positive. The young people see many problems and troubles in the new technology. The engineering education needs to change and show its important meaning also for the youth. Issues concerning sustainable development in the all education are increasingly relevant now and in the future. Enterprises need the best engineering education, but the focus ought be on quality, not on quantity. The Ministry of Education in Finland has a structure development program which aims at creating a new structure and new degree programmes in the Finnish engineering education.

2. BACKGROUND

The Finnish higher education system has two parallel sectors: universities and universities of applied sciences also called polytechnics or AMK institutions.

2.1. University education

Universities concentrate on academic and scientific research and education. Polytechnics are more oriented towards working life and they base their functions on the high demands of working life. The education and training provided by the polytechnics respond to labour market needs. Their task is also to conduct R&D which supports education and promotes regional development.

Finland has 20 universities. They enjoy the principles of academic freedom and autonomy, and hence, universities are very independent in their decision-making. All universities are state-run, the government providing some 70% of their budgets.

The total university enrolment is currently over 176 000 students.

All universities carry out research and confer doctorates. Each university has also a centre for continuing education.

Student intake, number of students and qualifications in universities, years 2003-2007

Year	Student intake	Share of females	Number of students	Share of females	Qualifications	Share of females
2003	20 782	55.8	169 846	53.5	18 197	61.3
2004	21 072	56.7	173 974	53.4	18 293	61.7
2005	20 858	56.6	176 061	53.7	19 176	61.8
2006	20 150	56.5	176 555	53.8	19 410	61.6
2007	19 648	57.4	176 304	54.0	22 310	63,0

Source: Statistics Finland

Table 1.

2.2. University of applied sciences education

The Finnish polytechnics system was built during the 1990's to create a non-university sector of higher education. It was founded on the institutions, which previously provided post-secondary vocational education and which have been developed to form a nationwide network of regional institutions of higher education, i.e. polytechnics.

Polytechnic education emphasises close contacts with business, industry and services, especially at the regional level. The degrees are designed to meet the changing requirements and development needs of the world of work, having a pronounced occupational emphasis, and qualifying graduates for various expert duties.

There are 25 polytechnics operating under the Ministry of Education. Most polytechnics are multi-field institutions and operate in several units.

Currently there are over 133 000 students registered at universities of applied sciences in Finland. Universities of applied sciences undertake some research and development with an applied and practical emphasis.

Student intake, number of students and qualifications in universities of applied sciences, years 2003-2007

Year	Student intake	Share of females	Number of students	Share of females	Qualifications	Share of females
2003	36 701	55.1	129 875	53.3	20 588	62.0
2004	36 483	56.3	131 919	53.7	20 821	62.4
2005	36 911	56.5	132 783	54,2	21 397	62.8
2006	36 276	55.7	132 560	54.3	21 006	63.6
2007	36 634	55.5	133 284	54.5	20 969	63.5

Source: Statistics Finland

Table 2.

2.3. Engineering education in Finland

Finland has 7 universities and 21 universities of applied sciences providing engineering education.

The total number of engineering students was 74,007 in 2009, 35,621 of which were university students and 38,386 were polytechnics students. The total number of graduated engineers in the same year was 9,000 (4,079 from universities and 4921 from polytechnics). (Statistics of the Ministry of Education)

Globally about one million engineers graduate every year, while the corresponding figure in Finland is about 9,000. This means that Finland cannot compete quantitatively.

In Finland, consequently, the primary focus must be on improving the quality of education, research and development in the field of technology.

The Ministry of Education has a structure development program for the Finnish higher education.

The goals are e.g. less university units, larger campuses, cooperation with degree programmes and also university fusions and alliances.

3. SOME FINNISH VISIONS, IDEAS AND ACTS

Many visions, strategies and acts for developing engineering education already exist. The National Cooperation Group for Engineering Education was assembled in 2007, and the development project of technical and engineering education began the following year. Moreover, many surveys, researches, inquiries and reports are constantly made.

3.1. The National Cooperation Group

The National Cooperation Group for Engineering Education was set up in 2007 in order to produce a national strategy for engineering education in Finland. The group has members from the Ministry of Education, universities, unions and labour market. The Group submitted its interim report "Well-being from Technology through Cooperation" in January 2008 and its final report "The National Profile Map" in 2009. The report has some significant visions and objectives for the Finnish engineering education:

> *"Finland endeavours to create the world's best innovation environment. A prerequisite for this is that our engineers are the most competent."*
>
> *"In order to reach the objective, the key issues are to develop the financing systems of tertiary education, improve teaching, increase internationalization, take into consideration challenges of the sustainable development and structural development of the higher education system."(Ref.II)*

The Cooperation Group has also prepared action plans for the development of the teaching and learning of engineering and how to better face the challenges of sustainable development. The Group defined five most important proposals:

- The number of higher education institutions and establishments of institutions providing engineering education must be reduced.
- The qualitative criteria of the budgetary funding systems of universities and polytechnics must be widely applied in addition to the criteria based on the volume of education and research.
- Universities and polytechnics must collaborate in developing professional societal communication to various target groups as the youth and the political decision makers.
- Finnish engineering education needs to be made a world famous brand: a trailblazer for the requirements of sustainable development and working life collaboration.
- Cooperation both between stakeholders of engineering education and with other actors in the innovation system must be further intensified. (*Ref.II*)

This profile map is a remarkable tool in writing new strategies for the engineering education and in realizing structural developments.

There was also a project called "Competencies through Learning", which was implemented as a part of the National Strategy Project for the Finnish Engineering Education. The abstract of the final project report states:

> *"The purpose of the project was to develop teaching of the engineering education at universities and polytechnics. The intention was to define how education must be developed in order to meet the strategic objective set by the National Cooperation Group for the Finnish Engineering Education: The best engineering education in the world is provided in Finland."*
>
> *"The starting point for the project work was an analysis of the anticipated skills and competencies that engineers need in the working-life in future. Learning objectives were defined based on the analysis of skill needs. Consequently, the project ended up with extending discussions to a number of questions and development needs including tertiary education institutions' operating culture, qualifications, steering of teaching and teaching methods."*

> *"Excellent problem solving skills are a key strength of the Finnish engineers. These skills are based on in-depth knowledge of technology and good competencies in math and natural sciences. However, in order to meet the skill needs of the labor market in the future, the present engineering education provided by the universities and polytechnics needs to be developed in several ways. Many competencies those are important in working-life, like business expertise, internationalization and sustainable development skills, do not get enough attention in education programs." (Ref. III)*

3.2. Sustainable development and education

According to the National Cooperation Group for the Finnish Engineering Education the mission of the Finnish engineering education is to benefit the people and the environment through providing knowledge and skills, research and innovations for the society and business life.

The youth values life on different ways nowadays than so called baby boom generation: egoism is over, money is not the first thing and ecological visions are important. Issues like sustainable development, healthy environment, climate change, clean water, energy sufficiency, well-being and quality of life are more and more under discussion. Therefore all universities want to answer to these challenges in their new strategies. The sustainable development is integrated in the most degree programmes of engineering education.

The National Strategy Project for the Engineering Education was created in order to find out, what kind of learning objectives sustainable development imposes on the Finnish engineering education. Furthermore, the task of the project was also to find out, how engineering education has responded to these challenges.

Therefore, a research study was conducted at the Finnish Association of Graduate Engineers TEK. Project researcher Annina Takala was responsible for conducting and reporting the study.

The research study consisted of an extensive literature survey and interviews of 66 experts representing all key stakeholders of engineering education. The leading Finnish experts on technology and sustainable development were also represented among the interviewees, the National Cooperation Group and the steering group of this research study.

This research report has many important points:

> *"Sustainable development is a nationally and internationally accepted political concept, in which the objective is to assure the prerequisites of good life now and in the future, locally, nationally and globally. The essential question is how all activities can be adapted to the ecological carrying capacity."*
>
> *"Technology plays a key role in responding to the challenges associated with sustainable development. For example, mitigating climate change and sustainable use of natural resources require new and innovative technology that has energy and material efficiency as its starting point. Engineers act as decision-makers and experts and play a decisive role in advancing sustainable development."*
>
> *"The main challenge is to achieve a holistic view on sustainable development that simultaneously takes into account the environmental, social and economic aspects, in addition to the temporal and spatial dimensions. Engineering education needs to prepare students better, than it currently does, for systemic and life cycle thinking. Challenges of sustainable development are interdisciplinary by nature. Cooperation between different professions and disciplines is needed."*

> *"The findings of the present research indicate that the Finnish engineering education already enhances sustainable development. However, sustainability is not an approach consciously chosen. The way in which sustainability is carried out is, for example, in the form of isolated courses and research projects. A complete picture of the overall situation is missing. In order to follow the mission of the Finnish engineering education, knowledge and skills related to sustainable development need to be included among the key learning objectives in all degree programmes of engineering." (Ref. IV)*

All these examples tell that we have to change and develop the engineering education. The world has changed and is changing, and especially young people's goals and values are different from those of previous generations. The future forces to come up with new ideas for education.

3.3. Engineering Associations' National Climate Plan for Finland

In the international project titled Future Climate – Engineering Solutions being implemented by various engineering organisations, the associations of each participant country have drawn up the profession's proposal for their country's national climate programme, wherein national structures are analysed and technology-based means for cutting emissions and for slowing down climate change are presented. Because the problem is a global one, also global methods are needed to solve it, but in this assessment the focus is on national solutions.

These recommendations were presented in Copenhagen in December 2009 to the UN Climate Change Convention.

Finland's contribution was drawn up in collaboration by the Finnish Association of Graduate Engineers TEK and the Union of Professional Engineers in Finland UIL. Education, e.g. engineering education , plays a major role in Finnish report:

> *"Education is in a key position in order that skilled people are available to develop technology also in the future. Expertise in sustainable development must be included in all education and training programmes in the field of technology, and this must be linked to core know-how. At the core of expertise in sustainable development there are the following: material and energy flow and energy efficiency, the ability and readiness to apply critical thinking, and system and lifespan thinking. In order that the objectives might be reached, it is necessary to clarify the foremost issues related to sustainable development and do so field-specifically and include them in educational programmes. Investments must be made in the quality of education and in the development of educational methods and learning environments." (Ref.V)*

The same thoughts are in new engineering education visions and strategies.

4. THE DEVELOPMENT PROJECT OF TECHNICAL AND ENGINEERING EDUCATION

The Ministry of Education and all Finnish universities of applied sciences have established a project titled INSSI (ENGIN in English documentation). This is a development project of technical and engineering education in universities of applied sciences and is going on until the end of March 2011.

4.1. INSSI project (engineering project) 14th May 2008 – 31st March 2011

This INSSI project has three main aims:

a) To increase to attractiveness of engineering studies so that number of applicants will rise at least 10 %
b) To shorten the studying time in universities
c) To decrease the number of interruptions of the studies.

The project contains three groups:

a) The group of structure development
b) The group of marketing
c) The group of teaching and learning methods.

The project has already organized some seminars and published two books about good learning practices.

The group of structure development has planned new structures for studies (common basic skills after which development skills will follow) and has suggested that in the future the number of the names of engineering degree programmes will reduce but maybe some new degree programmes need to be created.

The group of marketing has made some television ads and created the website in order to increase the interest in engineering education amongst the youth. The website "insinooriksi.fi" ("to become an engineer") has e.g. good hero stories of young engineers, an engineering quiz and an engineering engine with which young people can find the best study programme for themselves.

The group of teaching methods has collected the best practices in engineering educations from all the Finnish universities of applied sciences. These practices (more than 70) are published in two books and many of them were presented during INSSI Forum on 17th – 18th March in Hämeenlinna. INSSI Forum collected more than 350 Finnish engineering teachers to discuss and to learn from each other.

4.2. The SME Inquiry

The Confederation of Finnish Industries EK explored the small and medium-sized enterprises leaders' opinions about polytechnic engineering education in the autumn 2009. Small and medium-sized enterprises (SMEs) form the vast majority of companies in Finland.

The inquiry was based on the intermediate results of the INSSI project and it was conducted in the form of web questionnaire. EK received response from 400 SME owner-managers and executives. The results of the inquiry were published in January 2010.

The results of the inquiry clearly demonstrate that there is a growing demand for technical and engineering skills in the ongoing structural change of the economy.

A common request of the respondents was to include methods of "learning by doing" abundantly in the education. According to them, a special skill of the polytechnics must be an exploring, developing and forward-looking dimension of this "learning by doing".

The inquiry proves that engineering education needs differentiation to meet the various demands. SME leaders strongly support reforms that are under way in universities of applied sciences.

These reforms include:

- Making the network of universities of applied sciences more effective through the so-called criteria of well-functioning campus,
- Bringing curricula closer to practice and problem-solving,
- Reforming learning environments and working methods,
- Linking internships and learning more closely together, and
- Increasing partnerships with enterprises

(*Ref. I*)

The INSSI project has a challenging task to merge enterprises' wishes with youth's style of living and learning, and the common economic situation.

5. CONCLUSION

The engineering education is meaningful and important for the firms and enterprises, for the economy and for the future. Changes in engineering education and new contents are obligatory. New Finnish visions and strategies are coming to all universities and degree programmes. They act as guidelines also for teachers and students – towards our future!

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Engineering Education in Service Systems

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Abstract: The world's first industrial engineering academic program was established at Penn State by General Beaver, then Governor of Pennsylvania, in 1908. Since that time, the Department has graduated more than 7000 students. In 2005 the department faculty made major changes in the curriculum with the vision of educating the World Class Industrial Engineer. The major innovation in the new curriculum is specialization tracks in manufacturing systems, service systems, and information systems. The emphasis of this curriculum is educating students on the principles, tools and techniques of the industrial engineering profession which can be applied to these tracks. The revised curriculum builds a strong foundation for the development of a professionally competent and versatile industrial engineer, able to function in a traditional manufacturing environment as well as in a much broader economy, including financial services, communication, information technology, transportation, health care, and consulting. Given the increasingly dominant role of services in the world economy, it is imperative that engineering curricula be systematically adapted to this significant shift. The aim of this paper is to present new courses developed to support the engineering services systems track along with some of the challenges faced in this effort. We will discuss in detail courses at the undergraduate and graduate level including Retail Services Engineering, Competitive and Sustainable Industrial Enterprises, Financial Engineering, Financial Services Engineering, and Information Technology for Industrial Engineering. We will conclude with a discussion on how these courses serve as a means for integrating the research efforts in the Center for Service Enterprise Engineering into the curriculum.

Keywords: Industrial Engineering, Service Systems, Service Enterprises, Curriculum Innovation

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1. INTRODUCTION

Modern economy can be broadly divided into three major sectors: agriculture, industry and services. Examples of services include advertising, broadcasting & news, call centres, consulting, education, entertainment, financial services (stock brokering, banking), government services, healthcare, hospitality, information technology, insurance, marketing, real estate, retail, transportation, and travel & tourism. Services has become a significant part of the world economy, employing about 40% of the work force and contributing about 63% to the world economic output. In the United States services employs about 77% of the work force and contributes about 77% of the GDP (CIA 2009). This has made services larger than the agriculture and industry sectors worldwide, and in the U.S., as shown in Figures 1(a) and 1(b). It is therefore imperative that engineering curricula be systematically adapted to this significant shift in the economy, which is consistent with the findings of the U.S. National Academy of Engineering (NAE) Committee on Engineering Education (CEE) (NAE, 2010).

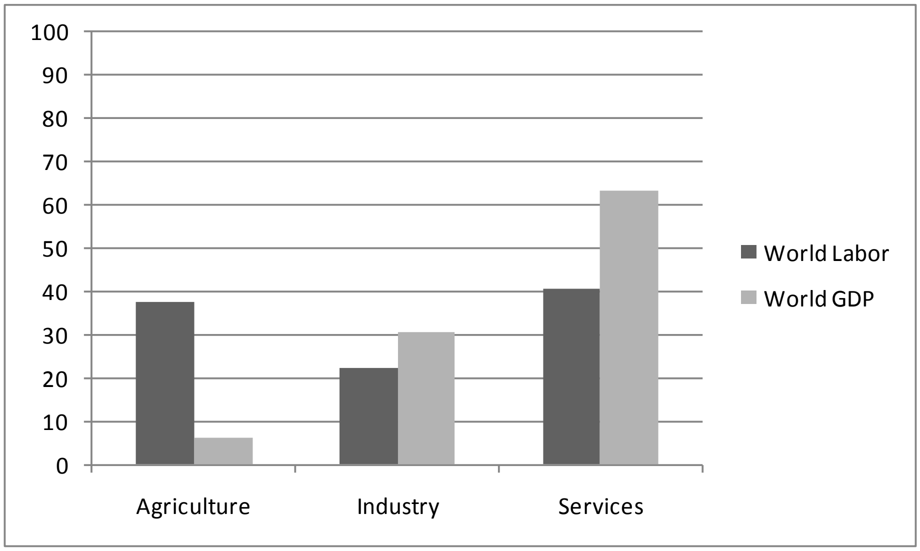

Figure 1 (a) Economy and labour by sector for the world

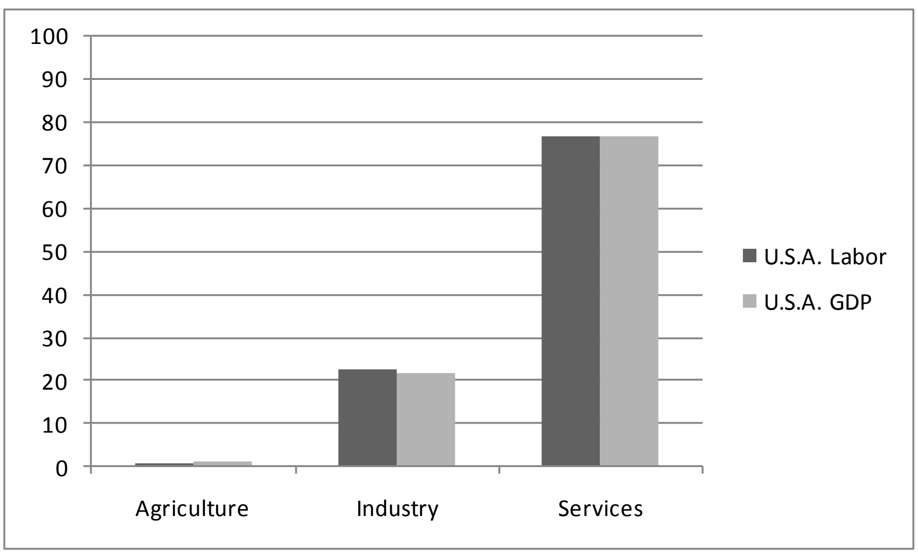

Figure 2 (b) Economy and labour by sector for U.S.A.

With this in mind, in 2005 the industrial engineering faculty at Penn State made major changes in the curriculum with a vision to educate the World Class Industrial Engineer. The major innovation in the new curriculum is specialization tracks in manufacturing systems, service systems, and information systems to equip engineers for new opportunities. The emphasis of this curriculum is educating students on the principles, tools and techniques of the industrial engineering profession which can be applied to these tracks. The revised undergraduate curriculum built on a strong foundation for the development of a professionally competent and versatile industrial engineer, able to function in a traditional manufacturing environment as well as in a much broader economy, including services. After the undergraduate curriculum revision, the Center for Service Enterprise Engineering was established in 2007, and several new graduate courses in services have also been developed and taught.

The rest of this paper presents new courses developed to support the engineering services systems track along with some of the challenges faced in this effort. We will discuss in detail courses at the undergraduate and graduate level including Retail Services Engineering, Financial Engineering, Financial Services Engineering, and Information Technology for Industrial Engineering. We will conclude with a discussion on how these courses serve as a means for integrating the research efforts in the Center for Service Enterprise Engineering into the curriculum.

2. UNDERGRADUATE CURRICULUM

The Institute of Industrial Engineers defines its members as "engineers concerned with the design, improvement and installation of integrated systems of people, materials, equipment, and energy. They draw upon specialized knowledge in the mathematical, physical, and social sciences together with the principles and methods of engineering analysis and design to specify, predict, and evaluate the results to be obtained from such systems." Many industrial engineers play important leadership roles in various organizations. Therefore the design of a curriculum for industrial engineering students needs to balance depth and breadth to prepare graduates for diverse roles in the overall economy. To further the vision of educating the World Class Industrial Engineer, the department has also developed exchange programs with universities in Japan, Dominican Republic, and Spain. These exchange programs are implemented through a 1-credit course in which students learn about the country, and visit the host university's country for a week. During the visit the students tour local manufacturing and service industries, sit in on classes to see how engineers are taught in other countries, and also visit cultural sites to get a better understanding of the people and history.

2.1 Curriculum

As in other engineering majors, IE students take courses in basic sciences and engineering, and general education during the first two years. After this IE students take courses required for the major, which are designed to introduce the student to basic Industrial Engineering. The overall curriculum requires 129 credits, and is summarized in Figure 2 (PSUIME 2010).

2.2 Specialization Track: Engineering Service Systems

Along with the required courses, students chose one of the three tracks of specialization: Manufacturing Systems Engineering, Engineering Service Systems or Engineering Information Systems. Since the studies regarding service industry is an interdisciplinary area, recommended course work in the engineering service systems track also includes courses from other departments as shown in Table 1.

1st Semester

MATH 140	***Calculus I***	***4***
EDSGN 100	Engr. Design & Graphics	3
ENGL 15 or 30	Rhetoric & Composition	3
CHEM 110	***Chemical Principles***	***3***
Arts, Humanities, Social Sciences		3
		16

2nd Semester

MATH 141	***Calculus II***	***4***
PHYS 211	***Mechanics***	***4***
CHEM 111	Experimental Chemistry	1
ECON 2 or 4	(Social Science)	3
Arts, Humanities, Social Sciences		3
First-Year Seminar		1
		16

3rd Semester

MATH 231	Calculus of Several Variables	2
PHYS 212	Electricity & Magnetism	4
CAS 100A/B	Effective Speech	3
+E MCH 210[A]	**Statics & Strength of Materials**	**5**
Arts, Humanities, Social Sciences		3
		17

4th Semester

MATH 220	Matrices	2
CMPSC 200, 201, or 202	Matlab C or Fortran Programming	3
MATH 250	Differential Equations	3
Science Elective [B]		3
~ Choose 6 credits from approved list		6
		17

5th Semester

+I E 302	**Engineering Economy**	**3**
+I E 305	**Product Design, Specification & Measurement**	**3**
+I E 322	**Probabilistic Models in IE**	**3**
+I E 327	**Introduction to Work Design**	**3**
MATSE 259	Materials, Properties & Processing	3
Health & Physical Activity*		1.5
		16.5

6th Semester

+I E 323	**Statistical Methods in IE**	**3**
+I E 405	**Linear Programming**	**3**
+I E 330	**Information Technology for IE**	**3**
Choose a manufacturing processing course[C]		3
Engl 202C	Technical Writing	3
Health & Physical Activity*		1.5
		16.5

7th Semester

I E 425	Intro to Operations Research	3
I E 408 or 419	Cognitive Work Design or Work Design-Productivity and Safety	3
I E 470	Manufacturing System Design & Analysis	3
Specialization Course[D]		3
Arts, Humanities, Social Sciences		3
		15

8th Semester

I E 453	Simulation Modeling for Decision Support	3
I E 480 W	Capstone Design Course	3
Specialization Courses[D]		6
Arts, Humanities, Social Sciences		3
		15

Courses listed in ***boldface italic type*** require a grade of C or better for entrance into this major.
+Courses listed in **boldface type** require a grade of C or better for graduation in this major.
[A] Students may substitute E MCH 211 and 213 or 213D for E MCH 210.
[B] Science Elective: Select from BIOL 141, CHEM 112, 202, MATH 310, 311W, 401, 405, 411, PHYS 214. (NOTE: Students taking the 2-credit PHYS 214 will need to take an additional credit to meet the 129 credit degree requirement).
[C] Select from IE 306, IE 307, IE 311, IE 464
[D] All undergraduates must take 9-credits (3 courses) of specialization track electives chosen from the Department's list. Of these 9-credits, a minimum of 6 credits must be IE courses.
~ Choose 6 credits: CMPEN 271 or EE 211, ME 201 or 300, E Mch 212, 3 credits from a minor upon completion of the minor as approved by the IE department, 3 credits any combination of Co-op or Internship, 3 credits of ROTC upon completion of the ROTC program.
*Students may satisfy this requirement with one, 3 credit GHA course or 3 credits of ROTC upon completion of the ROTC program.

Figure 3 Overall undergraduate curriculum in Industrial Engineering

I E 408 Cognitive Work Design	I E 478 Retail Services Engineering
I E 418 Human/Computer Interface Design	IE 497x Service Enterprise Engineering
I E 419 Work Design - Productivity and Safety	IE 497x Healthcare Systems Engineering
I E 433 Regression and Design of Experiments	BIOE 402 Biomedical Instrumentation and Measurement
I E 434 Statistical Quality Control	BIOE 406 Medical Imaging
I E 436 Six Sigma Methodology	C E 422 Transportation Planning
I E 454 Applied Decision Analysis	C E 424 Optimization in Civil Engineering Systems
I E 466 Concurrent Engineering	Math/Stat 416 Stochastic Modeling
I E 467 Facility Layout and Material Handling	M E 446 Reliability and Risk Concepts in Design
I E 468 Optimization Modeling and Methods	STAT 462 Applied Regression Analysis
IE 497x Data Envelopment Analysis	

TABLE 1 List of courses for the Enginering Service Systems Track

3. COURSES

This section introduces some courses which are newly developed for the engineering service systems track.

3.1 Information Technology for Industrial Engineering

This is a required course for all undergraduate students in the major. Objective of this course is the study and application of computing and information technology to industrial engineering. It covers an overview of Enterprise Information Modeling, Analysis of Data Bases, Data Mining, Internet technologies, and Object Oriented Programming. Specific application examples from industrial engineering, manufacturing and service areas are discussed. Hands-on lab exercises complement the lectures, and provide a source of practical examples.

3.2 Retail Services Engineering

Objective of this course is to understand modern retail industry with focus on their operations and information technologies. The course starts with an overview of the basics of types of retailing, their channels, and economics of their operations. Much of the emphasis in the course is on processes and information technologies used in retail industry such as point of sale systems, barcode, RFID/EPC, data warehouse and analytics for decision support. An important part of the course is the group project. This course is also allowed for graduate credit in the Department.

3.3 Service Enterprise Engineering

This course covers the use of tools from industrial engineering and operations research to build mathematical models and to develop methodologies for optimal design and control of service systems. Topics covered include overview of service systems, quality and evaluation of service, financial engineering, supply chain engineering, and revenue management.

3.4 Competitive and Sustainable Industrial Enterprises

Energy and emissions are becoming increasingly important in manufacturing and service enterprises in the U.S and around the world. Engineering decisions in product design, manufacturing, distribution, usage, and disposal all impact energy consumption and emissions. Manufacturing and service enterprises are initiating sustainability in their operation as a part of their corporate social responsibility mission. This course, which is being developed, will focus on understanding the fundamentals sustainability. Technical focus will be on engineering models to characterize energy consumption and emissions in manufacturing and service processes.

Tentative topics include, industry megatrend in sustainability; various forms of energy used in industry such as renewable, hydrocarbon fuels, electricity, steam, and compressed air; emissions and natural resource consumption in various processes; energy efficiency improvements through lighting and HVAC; Life Cycle Assessment (LCA) and impact during design, manufacturing, packaging, transportation, usage and disposal; LCA of CFL bulbs, wind turbines, solar PV panels, storage batteries, and data centers; energy and emission impact in tourism and entertainment services.

3.5 Financial Engineering

This course is an introductory graduate level course in financial engineering. It consists of cash flow analysis, options pricing, real options, and applications. The lectures include theories from a portfolio selection using a nonlinear programming method to American option pricing using a stochastic dynamic programming method. Based on the lectures, the students are encouraged to develop their ideas as a term project and apply the state of the art methodologies to real world problems.

3.6 Financial Services for Enterprise and Supply Chain Engineering

Objective of this course is to study current and emerging electronic financial services used in enterprise and supply chain operations. Emphasis will be on technologies used in these services and how they can be used for improving operations of individual enterprises and across global supply chains. Topics covered include electronic finance, electronic payments, electronic trading, service oriented architectures, treasury technology, and enterprise and supply chain decisions based on financial services. This is an entry-level graduate level course suitable for students in engineering that is scheduled to be taught for the first time during Fall 2010.

3.7 Distributed Systems and Control

The objective of this course is to study current research and engineering challenges in distributed systems and control in the context of manufacturing and service enterprises, and supply chains. Emphasis will be placed on understanding the dynamics and computational aspects of decision making and control algorithms in integrated enterprises. Recently several new open architecture standards have emerged for control and information systems in industrial enterprises. These standards have been largely driven by industry to reduce the cost of integrating and configuring a new breed of distributed enterprises to be engineered. This course deals with the multidisciplinary aspects of controls, computing, and communication in this rapidly evolving area. Term project topics in the course have included hospital emergency room scheduling, call center management, distribution logistics, and hospitality services.

These courses have been developed by individual faculty members with expertise and interest in the corresponding subject matter. Availability of the faculty to teach these courses has been quite good essentially because of the relatively large number of faculty ($\approx$ 25) in the department. Another encouraging factor is that these courses have been well subscribed by the students. Some of the common challenges in developing these courses include lack of good text books, and occasional perception that some of the topics may be better covered in other majors. However, these courses have been well received by industry which sees the need for engineering graduates trained in these topics.

4. SERVICE ENTERPRISE ENGINEERING CENTER

The Center for Service Enterprise Engineering (CSEE) was established within the Department in January 2007. It is the first such academic center in the U.S., devoted solely to the study and practice of service engineering. CSEE has been initiated with a $1 million gift from Harold and Inge Marcus, and to-date has received additional research funds of over $1.4 million from a variety of sources including NSF, NIST, USDA, USDE, and the Ben Franklin's Center of Excellence Award. The center constitutes of 8 faculty members and 17 graduate students actively engaged in research in various aspects of service enterprise engineering. The remainder of this section will describe the main areas of research currently being pursued in CSEE along with related courses that enable integration of research and teaching.

4.1 Revenue Management

At CSEE, revenue management (RM) research includes pricing, resource allocation, and demand management. The aim of RM is to enable companies to sell the right resources to the right customers at the right time and the right price. The goal of RM is to extract all willingness to pay. We analyze and forecast demand, competitor behaviour and customer behaviour in order to optimize resource allocation and cost structure. RM can be applied to a variety of industries including security services, health care, and golfing.

Related coursework

IE 468: Optimization Modeling and Methods	IE 478: Retail Engineering
IE 497x: Service Enterprise Engineering	IE 505: Linear Programming
IE 516: Applied Stochastic Processes	IE 519: Dynamic Programming
IE 520: Multiple Criteria Optimization	IE 554: Production, Planning and Control
IE 562: Expert Systems Design in Industrial Engineering	IE 570: (SC&IS) Operations Research in Supply Chain
IE 589: Dynamic Optimization and Differential Games	IE 597x: Financial Services for Enterprise and Supply Chain Engineering
IE 597x: Introduction to Financial Engineering	

4.2. Customer Service Center Test-bed

The research aim here is to develop a customer center test bed (CCTB) as a reconfigurable, customized offline software package that simulates the realistic call center environment based on preset scenarios. The setup of the software can be changed easily by editing the scripts and processes that model various scenarios that need to be evaluated based on customer's requirements. CCTB example applications include trucking, health care, and public emergency call centers.

Related coursework:

IE 408: Cognitive Work Design	IE 418: Human/Computer Interface Design
IE 462: Expert Systems Design	IE 553: Engineering of Human Work
IE 557: Human-in-the-Loop Simulation	IE 558: Engineering of Cognitive Work
IE 567: Distributed Systems and Control	IE 578: Using Simulation Models for Design

4.3. Service Process Modeling

CSEE is researching new techniques for service process modelling for (1) better understanding of user satisfaction (2) re-engineering customers' IT systems that better support process requirements (4) cultivating innovation-rich culture throughout customer's service enterprise, and (5) helping incubate more innovative services to meet the changing needs of customers. Some of the modelling techniques have been used for analyzing enterprise transformation projects where complexity of existing and transformed processes were quantified using metrics based on information theory. Such techniques have been used for applications in healthcare, supply-chain services, and in security operations.

Related coursework:

IE 462: Expert Systems Design	IE 424: Process Quality Engineering
IE 522: Discrete Event Systems Simulation	IE 466: Concurrent Engineering
IE 578: Using Simulation Models for Design	IE 567: Distributed Systems and Control
IE 453: Simulation Modeling for Decision Support	IE 584: Time Series Control & Process Adjustment

5. CONCLUSIONS

There is a significant increase in the role of services in the economy worldwide. In order to adapt to these changes Penn State's Industrial Engineering Department has developed a track in Engineering Service Systems at the undergraduate level. The emphasis of this curriculum is educating students on the principles, tools and techniques of the industrial engineering profession. The revised curriculum enables the development of a professionally competent and versatile industrial engineer capable of contributing to a broad economy, including financial services, communication, information technology, transportation, health care, and consulting. The paper described the overall curriculum and the some of the new courses developed to support the service systems track. Courses especially at the graduate level serve as a means for integrating the research efforts in the Center for Service Enterprise Engineering in the areas of revenue management, customer satisfaction, and enterprise innovation.

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HEAT AND MASS TRANSFER IN THE LONG RAINS: DOING ENGINEERING UNDER A MANGO TREE

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Abstract: Academic engineering exists primarily as a monoculture. In common with agricultural monocultures, it has a genetic (inherited) uniformity across international boundaries and climatic zones; it demands continuous and expensive inputs (of equipment, staff- and laboratory- time) and is highly susceptible to drought and common diseases (staff shortages, curriculum revision . .) A typical engineering degree is specialised, rarified, expensive – and often impractical and ill-suited to the demands made on it by societies struggling to take control of their own development.

In many practical situations, some basic engineering knowledge and understanding is all that is necessary to empower practitioners to take control of their own learning and investigations. Education "in the field" can give a major boost to students' motivation and self-learning. Once they have grasped some fundamental principles in their area of concern, they can take their own measurements, draw their own conclusions, and devise effective, locally-applicable engineering solutions to the practical problems they confront.

Examples are cited from the author's engagement with Knowledge Transfer Partnerships in Africa; but the principles are more widely applicable to non-specialist engineering teaching and possibly to short courses in industry.

Keywords; self-learning, development, drying, energy efficiency

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1. INTRODUCTION

Engineering has become a reserved, professional discipline, and rightly so in many instances. Design and construction of big dams; of nuclear power plant; of offshore platforms, refineries and passenger aircraft are properly the province of highly qualified and certificated specialists. But the mystique that has come to surround engineering may also be an impediment to the active involvement of other scientifically- or technically-educated people in the solution of fundamental day-to-day problems. In countries where the pool of such educated and skilled manpower is small, all available resources need to be mobilised in support of national development goals. To do this, people with little or no engineering training need to be equipped with the intellectual tools and techniques to tackle basic problems as they occur (and to recognise where their knowledge is inadequate to the task) and the motivation to learn what they need to know. This is well illustrated in the classic case of motor car maintenance – an important part of the upbringing of young men in many and diverse societies was/is the acquisition of skills of fault diagnosis and repair – usually by assisting their slightly older and more skilled peers. (Regrettably this particular skill acquisition has been eroded over the last two decades by the increasing prevalence of electronic ignition, computer diagnostics and non-repairable components).

This basic grasp of mechanical operation has propelled generations of young people into the study of engineering; and has endowed very many more with an appreciation of things mechanical. But increasingly, academic engineering has taken a very different path and has come to exist primarily as a monoculture: a uniform diet of basic principles and a set of remarkably similar edifices built on these. In common with agricultural monocultures, academic engineering exhibits a genetic (inherited) uniformity across international boundaries and climatic zones; it demands continuous and expensive inputs (of equipment, staff- and laboratory- time) and is highly susceptible to drought and common diseases (staff shortages, curriculum degenerancy. .) A typical engineering degree is specialised, rarified and expensive (Salter 1995) – and this may often mean that it is impractical and ill-suited to the demands made on it by poorer societies and developing countries that are struggling to take control of their own development. But there are a variety of styles of learning, suited to different educational stages and objectives (Goldberger 1984, Beard & Wilson, 2002); and these can be deployed appropriately to meet a variety of educational needs.

In many practical situations, some basic engineering knowledge and understanding is all that is necessary to empower practitioners to take control of their own learning and investigations. But traditional classroom-based education doesn’t imbue a “learning-by-doing” approach: passive- and rote-learning are the styles most usually adopted in the classroom. The challenge to develop and transmit engineering expertise that is inclusive, and accessible to individuals with only a modest educational attainment, is not often taken up. This has been particularly noted by respondents to the Harvard Africa Higher Education Student Survey Project (2008).

Education “in the field” can give a major boost to students’ self-motivation and self-learning. Once workers – from a wide variety of educational backgrounds, and none – have grasped some fundamental principles in their area of concern, they can take their own measurements, draw their own conclusions, and devise effective, locally-applicable engineering solutions to the practical problems they confront. Two specific examples, both from Knowledge Transfer Partnerships in Africa, are described below, and an attempt is made to draw some more generally applicable conclusions. In each case a short, intensive, practical on-plant course was devised which enabled factory workers, ranging from Form 4 leavers to degree qualified engineers, to take control of their own learning, make and interpret appropriate measurements on plant, and design measures to reduce energy costs, improve product quality and boost output and profits.

2. AFRICAN KNOWLEDGE TRANSFER PARTNERSHIPS

2.1 The African model

“AKTPs” were instituted in four African countries: Nigeria, Ghana, Kenya and Uganda, in 2006, following the model of KTPs (formerly Teaching Company Schemes) long established in the UK. The African model has four elements:

1. Company identifies a significant issue/problem/opportunity requiring input of time and expertise to which the company may not have ready access. It commits to employing an appropriately qualified graduate as a KTP Associate (normally recently graduated; possibly with a Masters degree) for two years to work specifically on this. There is no commitment to continue the employment beyond this time.
2. KTP office identifies local academic staff who should be able to advise and contribute effectively to the project; they will be seconded by their University, and paid from KTP funds, for up to 1 day/week to work alongside, and supervise, the KTP Associate.
3. Advert placed, interviews held and Associate appointed.
4. Additional support is provided by local KTP officer who may engage an overseas expert to complement the supervisory team, and possibly arrange appropriate training for the Associate and others.

Funding for seconded academics and for the local and international Advisers has been provided through the British Council offices in Lagos, Accra, Nairobi and Kampala. These offices have also played a pivotal role in the provision of training for the Associates, in monitoring of work in progress (through a “Local management committee” for each project) and in the evaluation of outcomes (British Council).

2.2 Significance of training

It will be evident that, for a project to be successful, there should be close cooperation between all the parties involved. Equally, if the impact is to extend beyond the initial 2-year project lifetime, then training should be extended to other company employees, with the active participation of local supervisors (“Knowledge Base” in KTP terminology). In the initial stages of AKTPs, “training” was rather narrowly defined as training the *Associate*; and as a newly-appointed Adviser I was asked to arrange 2 weeks of intensive laboratory training in the UK, implying 10 days of dedicated supervision/training time, plus time spent in preparation. The alternative would be to carry out training on-site, where other company employees could reap the benefits – and where the local academic staff could also become involved.

2.3 Development of a training model

The requirements for such on-site training were assessed as being:

1. Accessible to staff from a variety of educational backgrounds
2. Practically based, to aid assimilation of theoretical concepts
3. Laboratory experimental measurements should complement those taken on plant
4. Participative; and arranged for small-group work
5. Challenging: participants have to tackle “open-ended” problems
6. Should help participants to “know what they don’t know” – and how to learn independently.

3. DRYING PROCESSES AND ENERGY USE

3.1 Uganda Clays, Kajjansi, Uganda

The first AKTP, (Case study A) at Uganda Clays, was aimed at identifying a replacement for (increasingly scarce and expensive) coffee husk as a furnace fuel. Key to this project was: how much energy is actually required in the process? If the energy required for processing clay products were used more efficiently, would the requirement for replacement fuel diminish – or disappear altogether? Allied to this question is that of the energy requirement for predrying of clay products before firing: that is, the latent heat of evaporation of the moisture content of the formed products, coupled with the efficiency with which this energy is supplied. And again allied to this is the *rate* of drying achievable: what factors affect drying rates, and how may drying rates be improved without deleterious effects on the products? Thus appropriate on-plant training should enable participants to:

- determine rates of air-drying of clay products under measured conditions of temperature and humidity
- be able to use a psychrometric chart - we used the simplified version from Wikipedia (2007) - to determine the effect on drying rate of changing atmospheric conditions
- carry out mass and energy balances to establish the airflows required at different stages of drying
- measure heat losses and hence propose energy-saving measures
- produce maps of airflow/temperature/humidity in different regions of the plant
- establish the effectiveness of any energy-saving measures implemented
- hence perform a cost-benefit analysis for different energy-saving proposals
- assimilate new concepts in energy efficiency, psychrometry and drying as needed

This “syllabus” had to be covered in three days, *and* produce sufficient results to demonstrate the effectiveness of systematic on-plant and in-lab measurements in improving drying and energy efficiency.

3.2 Course preparation

Local arrangements, including the manufacture of a laboratory tunnel dryer, (Figure 1) were in the hands of the Associate. My own preparation was based on a brief earlier visit; and I came equipped with an airflow/temperature/humidity meter and telescopic probe for on-plant measurements (Figure 2).

Figure 1: locally-constructed tunnel dryer

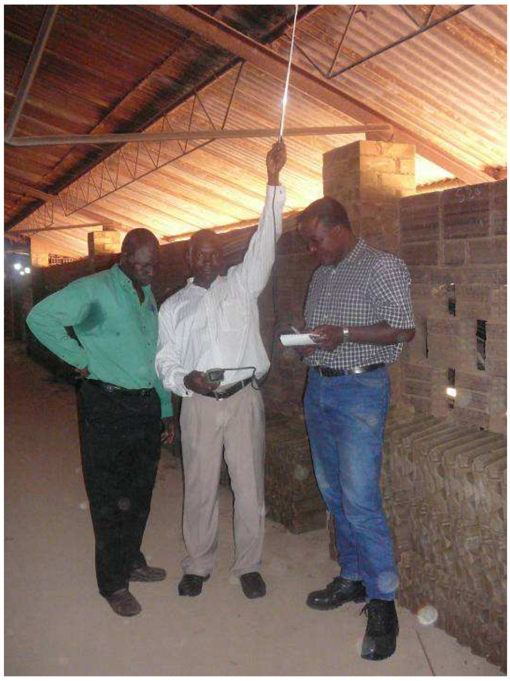

Figure 2: using the airflow/temperature/humidity probe

3.3 Course operation

The class composition was as described in Appendix 1. Given the limited possibilities for classroom teaching with so disparate a group, the carefully-prepared technical presentations had to be abandoned and the whole class took a tour of the plant. At each stop, a staff member associated with that part of the plant was asked to give a basic description of the processes being carried out and problems experienced; and all participants were encouraged to ask questions – moderated in such a way as to eliminate any embarrassment through being unable to answer on the spot. Thus within two hours the participants built up a catalogue of plant-related issues for study.

Back in the classroom, these issues set the agenda: participants decided what they "needed to know" in order to understand the drying processes and energy use on the plant; and determined how laboratory measurements taken under controlled conditions could be used to calculate drying rates. Thus armed, participants were divided into multi-ability groups and assigned tasks that they had identified during the walk-round. These included measuring, and proposing ways of improving, airflow distribution in predryers and "artificial dryers"; the effects of insulating hot-air ducts; and re-using exhaust air streams. Simple calculations and the use of psychrometric charts led to each group developing "solutions" that were then reported to, and discussed by, the whole workshop. Several innovations were made "on the hoof": a cardboard-box model of one of the drying sheds was constructed to demonstrate how airflows might be redirected; groups adopted and refined the measurements and calculations made by others; a spreadsheet was developed for recording spatial data around the plant.

The principal outcome was the skills and enthusiasm acquired by participants over a short period, ensuring that energy efficiency remained on everyone's agenda, and became a common currency of discussion on the plant – still being pursued actively on return visits made months later.

3.4 Adapting the experience

The second AKTP, (Case study B) at Mpanga Growers Tea Factory Limited, Fort Portal, Uganda had a number of strands: securing a sustainable supply of fuelwood from company plantations for raising steam used in the drying of tea; improving energy efficiencies across the board; and treating plant effluent. Again a key consideration was: *how much* energy is actually required in the process? If the steam generated and electricity used in tea processing were used more efficiently, what would the requirement then be for fuelwood and power?

3.5 A plant tour

The objectives of on-plant training of local staff were very similar to those at Uganda Clays; though the makeup of the staff group (Appendix 1) was yet more diverse. Building on the earlier experience, the 2-day course was designed from the outset to be plant-based, with concepts developed in the classroom as participants identified what they needed to know. In order to obtain the full involvement of staff – including those with no technical background at all – I used the "elephant and blindfold" method of asking each participant to describe "what do you see?" at each location. First stop – the woodpile (Figure 3), which provided a range of answers:

- Forester: *Eucalyptus grandis*
- Boilerman: 2 months' supply of fuelwood
- Auditor: a lot of working capital
- AKTP Associate: a stack of fuel open to the rains
- Administrator: a pile that might fall on someone

- Myself: trees that are not photosynthesising!

Using this technique it was possible to establish the perceptions and level of understanding of participants, and hence pick tasks of differing degrees of complexity that would “stretch” participants appropriately.

Figure 3: Fuelwood stacks at Mpanga Growers

Figure 4: Airflow and humidity measurements during “withering” of tea

In the event, assigned tasks ranged from an attempt to characterise drying rates in the “withering” (predrying) process (Figure 4), to measuring power usage by drives on the fermentation section (Figure 5), and studying the effectiveness of the system that has been installed to recirculate hot (and humid!) exhaust gases back to the fluidised bed dryer (Figure 6).

Figure 5: Drives in the fermentation section

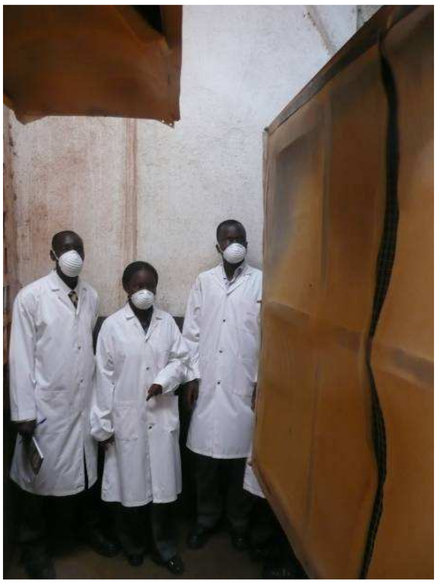

Figure 6: Sampling the FB dryer exhaust!

3.6 Implementing the findings

Each of these assignments gave rise to significant findings about plant operation and energy use:

- It was established that the withering process is extremely sensitive to the distribution of leaf on each withering trough; leading to the adoption of an operating procedure to be followed in manual spreading of the leaf.
- Replacement of oversized motors, together with rebalancing of phases, has led to a major reduction in power costs to the plant.
- Using the psychrometric chart, participants themselves discovered that recirculation of humid air prolonged the drying process and thus gave rise to an *increased* steam requirement per kg of tea! Performing these calculations gave participants the confidence to produce an embryonic design for an air-to-air heat exchanger for heat recovery.

Figure 7: Explaining the findings of a plant survey, Mpanga Tea Growers.

Figure 8: Next stop, hydropower!

But again the most significant outcome has been the commitment of staff to make continuous improvements to energy efficiency on the plant, both for their own benefit and for that of the environment. Keighley (1997) makes specific reference to the lasting impact of such learning experiences, particularly with reference to outdoor, “classroom without walls” experiences (Pritchard, 2008). And following the termination of the AKTP, this work continues. A newly-appointed forester is designing a solar drying shed for harvested timber, and a volunteer “energy group” continues to monitor energy usage and propose energy-related operating improvements.

4. CONCLUSIONS

These two Case Studies demonstrate that basic engineering concepts may be assimilated and applied by workers who have little or no specialist engineering background. Short but intense workshop-style activities provide an appropriate context for learning new techniques and applying new insights. By following through their findings to the stage of making alterations to practices and processes on the plant, participants have been empowered to become innovators in their work.

Whilst in these examples the structure and continuity have been provided by AKTPs, the principal driver has been the companies' commitment to the process and to implementing required changes. In the circumstances, these workshops have proved to be both e**ffective** and an **efficient** use of the facilitators' time. Given the acute shortage of both engineering teachers and engineers in many African countries, this model offers an alternative route to engineering innovation that may be more widely applicable. The success of this mode of learning suggests it should be effective in undergraduate teaching, as a means of enabling students to cross the existing and well-fortified boundaries of specialist disciplines in engineering; and possibly also in industry-based short courses.

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Appendix 1: Educational Backgrounds of Participants

At Uganda Clays, December 2007:

Graduates:	Ceramics	1
	Elect Eng	1
	Civil Eng	1
	Energy Eng (MSc)	1*
Diplomas:	Civil Eng	1
	Ceramics	5

*The AKTP Associate on this project

At Mpanga Growers, July 2009 & Feb 2010

Graduates:	Mech Eng	1
	Agric Eng	2*
	Agriculture	1
Diplomas:	Mech Eng	2
	Elec Eng	1
Certificates:	Mech Eng	2
	Elec Eng	4

Plus internal auditor, admin, & factory asst.

GENERAL ELECTIVES IN CIVIL ENGINEERING

AND COMPUTER SCIENCE

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Abstract: In 2005, University College Dublin (UCD), introduced the Horizons initiative that resulted in the development of fully modularised, semesterised and credit-based degree programmes. One of the key features of the initiative was the introduction of a degree of elective choice for students in the first three years of their undergraduate studies. Students can select two modules out of the twelve modules they take each year from any programme across the University. This paper examines the impact of the Horizons initiative on two disciplines in University College Dublin, namely, Computer Science and Civil Engineering. Examination of the data shows that a significant number of the students (approximately two-thirds of Civil Engineering students and approximately half of Computer Science students) choose electives outside their programme areas of study. Few non-Civil Engineering students (5%) avail of electives offered by the programme, while in the case of Computer Science a significantly greater number (46%) avail of the opportunity to study Computer Science electives.

Keywords; civil engineering education, computer science education, core modules, elective modules, breadth, depth.

1. INTRODUCTION

The development of undergraduate university education has been profoundly affected by the thoughts of two men - Wilhelm von Humboldt and Cardinal John Henry Newman - both of whom wrote extensively on the subject of university education in the 19th century. In 1810, Von Humboldt, the Prussian philosopher and minister of education, established a university in Berlin with the unity of teaching, research and graduate education as one of its basic principles (Albritton, 2006). The teaching efforts of all academics were directed towards the production of either future investigators or future professionals whose work depends upon a sophisticated knowledge base. This 19th century German model of higher education was the model emulated by several of what were to become the most prestigious universities in the United States.

Newman had quite a different view of the purpose of an undergraduate education. In 1852, he wrote his treatise called "The Idea of a University", a work still widely regarded as the most influential attempt to define a university education. Newman defends the value of learning for its own sake and vigorously opposes the notion of specialisation. According to Newman, undergraduate education "is the education which gives a man a clear conscious view of his own opinions and judgments, a truth in developing them, an eloquence in expressing them, and a force in urging them."

During the early years of the 20th century, undergraduate curricula at leading universities worldwide gradually evolved in a direction which is a compromise between the broad undergraduate education espoused by Newman and von Humboldt's philosophy that a student study one particular subject in depth. Breadth is achieved by requiring students to take courses in the arts and sciences while depth is achieved by requiring students to select a major in which a student is required to take a prescribed number of modules in a single discipline.

For example, at Yale University in the U.S.A., an undergraduate must take 36 courses over 4 years. *Breadth* (*distribution*) is achieved by requiring students to take at least two courses in the arts and humanities, two courses in the sciences, two courses in the social sciences, two courses in quantitative reasoning, two courses in writing skills, and at least one course to further their foreign language proficiency (Yale University Academic Requirements, 2010). Thus at least 11 - or almost 1/3 - of a student's total of 36 courses are employed to meet the requirement of breadth. *Depth (concentration)* is achieved by requiring students to select a major from among the more than 70 major programmes available. A major programme usually includes 12 courses in a single discipline taken for the most part in the final 2 years.

In Ireland, there is now some element of elective choice by students in practically all undergraduate programmes. The most common use of elective choice is to allow students to specialise in later years in particular areas of their main discipline. Elective options that allow students to explore other disciplines outside of their main area of specialisation have been much rarer. University College Dublin (UCD) has been at the vanguard of leading universities by introducing significant elective choice for students throughout most of their undergraduate years (UCD Horizons, 2005). This initiative will be more fully described in the next section.

There have been numerous calls to broaden the education of engineers and thus prepare them to serve society with an awareness of and sensitivity to the cultural, political, economic and social dimensions of their work (Canadian Academy of Engineering, 1999). This paper will present the experience of two disciplines in the College of Engineering Mathematical and Physical Sciences in UCD, namely, Civil Engineering and Computer Science, in providing a broader education through the provision of non-programme electives for their students.

2. UCD HORIZONS

In keeping with the philosophy of Newman, the founder of UCD, the introduction of the UCD Horizons initiative in 2005 resulted in the development of fully-modularised, semesterised and credit-based degree programmes. Modular degrees provide a more flexible, faster and cost-effective way to educate the growing number of students entering third-level education (Betts and Smith, 1998). Under the re-structured curriculum at UCD, in a given academic year, students choose *core* modules from their specific subject area, a number of *options* (if applicable) and *elective* modules, which can be chosen from within the student's programme of study (in-programme electives) or from any other programme across the entire University (non-programme or general electives). The philosophy underlying this curricular transformation is to give the freedom of choice to students to broaden their knowledge in different areas or deepen their knowledge in their chosen programme of study. Crucially, Horizons facilitates the formation of 'creative and innovative graduates', central to UCD's Strategy for Education and Student Experience (2009 – 2013).

General electives can be categorized as being either: (a) general interest (e.g. improving foreign language competence) or (b) generic/transferrable skills (e.g. research skills). The evolution of general electives at UCD and their impact on the undergraduate Civil Engineering and Computer Science Programmes since the inception of the Horizons initiative will be described below. The general modular structure at UCD is summarized in Table 1.

Module		**Comment**
Core		Students are required to take these modules
Options		Students may be required to select a number of modules from a specified suite of modules
Electives	In-programme	Students can select a maximum of 2 modules from a suite of modules offered by the programme
	General	Students can select a maximum of 2 modules from any programme across the University, subject to timetable and space restrictions

Table 1 General modular structure at UCD

3. ELECTIVE POPULARITY ACROSS UNIVERSITY

The highest demand for elective places across the University is in modules offered by the Colleges of Arts and Human Sciences and that particular subject areas in these Colleges are significantly more popular than those in the other Colleges of the University (Table 2). In the context of the present discussion, examination of Table 2 shows that Computer Science features amongst the list of most popular general electives, while no general electives offered by Engineering feature. A more detailed analysis of the data pertaining to these two disciplines will be presented below.

Subject area	Number of students
Languages	2009
Nursing Studies	1614
Psychology	846
Economics	765
Sports Management	678
Computer Science	673
Politics	644
History	605
Physiotherapy	602
Philosophy	589
Law	560
English	515
Geography	401

Source: Michael Sinnott, Director of Administrative Services, Registrar’s Office, UCD

Table 2 Subject areas with largest number of elective places taken in 2008-2009

4. CIVIL ENGINEERING

The UCD Civil Engineering bachelor’s degree has traditionally been a four-year 240-credit degree programme, although, in line with Engineers Ireland and the Bologna requirements, is moving gradually to a two-cycle 5-year degree structure. Table 3 outlines the number of core, option and elective modules that students of the current 4-year Civil Engineering programme take in each Stage (Year) of their studies.

	Core	Option	Elective
Stage 1	10	0	2
Stage 2	10	0	2
Stage 3	10	0	2
Stage 4	8	4	0

Table 3 Modular structure of the 4-year Civil Engineering degree programme

In respect of the elective choice, students can choose either:

(a) two in-programme electives which enable students to deepen their engineering knowledge,
(b) two non-programme (general) electives which allow students to widen their knowledge in modules of general interest to the student or
(c) one in-programme elective combined with one general elective.

In-programme electives are provided in stages 2 and 3. For example, for second year Civil Engineering, the following in-programme electives are offered:

CVEN20100 Applied Mechanics

MEEN20030 Applied Dynamics

MEEN10020 Materials Science

EEME10010 Energy Challenges

The popularity of the electives for the 2008-2009 academic year is shown in Fig. 1. The Figure is presented in terms of 'student equivalents' (2 elective modules per student). It should be noted that students could choose two in-programme electives, two non-programme electives or one in-programme elective plus one non-programme elective. Examination of Fig shows that less than a third of the students (28%) choose electives from within the programme, while more than two-thirds (72%) of the students chose from 60 modules outside the programme across the University. Note that the number of core module student equivalents does not exactly equate to the sum of the in-programme and non-programme student equivalents because the numbers include repeat students. It is also interesting to examine the popularity of engineering electives vis-à-vis students from outside the programme. In respect of the four in-programme electives listed above, only 19 in number of the 378 students (5%) taking these four electives were non-engineering students.

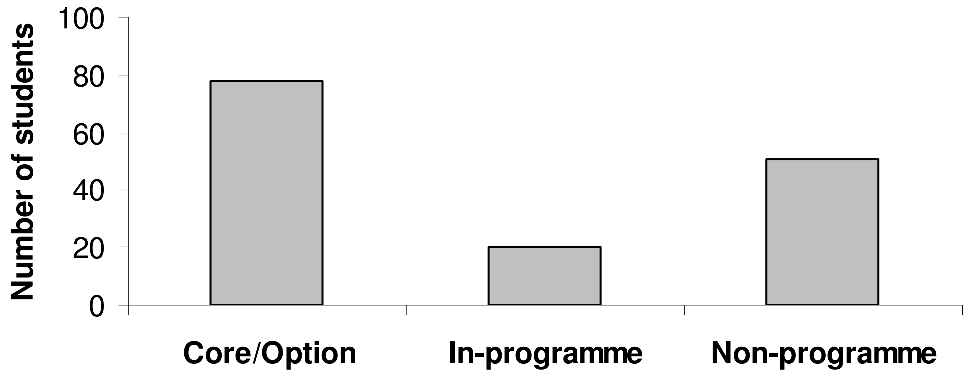

Fig. 1 Popularity of elective provision for second year

Civil Engineering in 2008-2009

5. COMPUTER SCIENCE

UCD offers fours programmes through which students can obtain degrees in Computer Science. The BSc (Computer Science) and BA (Computer Science) programmes, taken by most students who take a degree in Computer Science, are four-year 240-credit degree programmes. Students can also obtain a four-year 240-credit degree in Computer Science through the general BSc programme and a three-year 180-credit degree through the general BA programme. While this multiplicity of offerings is somewhat complex, it does offer students a huge choice and enormous flexibility, both in terms of the amount of Computer Science they may study and the other modules they may take. This flexibility is demonstrated in Table 4, which gives an outline of the number of Core (C), Optional (O) and Elective (E) modules students studying Computer Science may take in each of the Stages of their studies.

	BSc (Computer Science)			BA (Computer Science)			B Sc			BA		
	C	**O**	**E**	**C**	**O**	**E**	**C**	**O**	**E**	**C**	**O**	**E**
Stage 1	5	5	2	4	6	2	4	6	2	4	6	2
Stage 2	7	3	2	6-10	0-4	2	7	3	2	4-10	0-6	2
Stage 3	10	0	2	6-10	0-4	2	10	0	2	4-10	0-6	2
Stage 4	12	0	0	12	0	0	12	0	0	N/A	N/A	N/A

Key: **C** = Core module **O** = Option module **E** = Elective module

Table 4 Summary of the types of module available in each Stage of the various Computer Science degree programmes in UCD.

While the original stated intention of the provision of electives in the Horizons system was to allow students to broaden their education through taking modules of general interest to them, Schools were subsequently encouraged to provide “in-programme” electives to allow students “go deeper” in their subject, i.e. facilitate students in taking extra modules, thereby allowing them to study their chosen subject to an even greater depth. The School of Computer Science and Informatics embraced this idea and immediately offered four non-programme elective modules in Computer Science:

COMP 20090 Introduction to Cognitive Science
COMP 20100 E-Learning: IT in Education
COMP 20130 Introduction to Computer Forensics
COMP 20140 Introduction to Project Management.

The first of these modules is a Level 1 (1st year level) module and may not be taken by Computer Science students; all the others are at Level 2 (2nd year level) and may be taken by Computer Science and other students in Stages 1, 2 and 3 (Years 1-3).

The goals of the School of Computer Science and Informatics in providing these general non-programme electives may be summarised as follows:

- To provide the opportunity for Computer Science students to study the subject in greater depth, as outlined above;
- To give non-Computer Science students the opportunity to study some Computer Science modules and thus gain some exposure to the subject;
- To give Computer Science staff the opportunity to design and give an introductory module in their specialist area or an area of research in which they have an interest.

The popularity of the electives for the 2008-2009 academic year is shown in Fig. 2. In respect of the four in-programme electives listed above, 191 in number (46%) of the total number of students (414) taking in-programme electives were non-programme students.

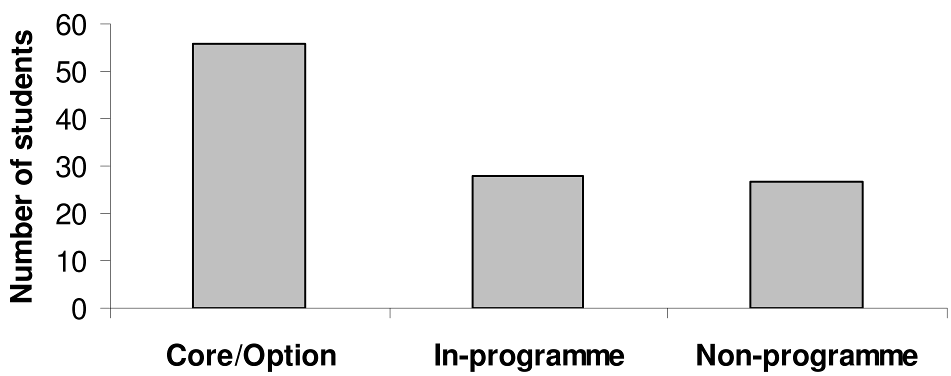

Fig. 2 Popularity of elective provision for second year Computer Science in 2008-2009

6. CONCLUSIONS

Examination of the data presented above shows that a significant number of the students (approximately two-thirds of Civil Engineering students and approximately half of Computer Science students choose electives outside their programme areas of study). Few non-Civil Engineering students (5%) avail of electives offered by the programme, while in the case of Computer Science a significantly greater number (46%) avail of the opportunity to study Computer Science elective modules.

7. ACKNOWLEDGMENTS

The UCD Fellowship Programme in Teaching and Academic Development supports this research.

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ASSESSMENT OF STUDENT BASED LEARNING APPROACH IN BIOMATERIAL SCIENCES

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Abstract: Student based learning (SBL) brought up new challenges to both students and teachers. A new approach to this methodology is being made in a biomaterials unit of biomedical engineering.

Over the years, traditional lectures were replaced by controlled small assignments. Topics and respective references are given to students. A web based platform (moodle) is an essential tool in this method since all the assignments, information and students' questions may be posted online.

Students are encouraged to search for more information on scientific search engines and engineering specific libraries.

The learning process is achieved by discussion and brainstorming in the classrooms.

Due to an evaluation system based on specific tasks and exams, one of the major drawbacks was the difficulty that students showed in understanding how the evaluation would occur. Though they had specific assignments, 50% of the evaluation was based in process learning.

Huge difficulties have been overcome by a trial and error process that leads to a smoother learning process.

The approval rate of the students that fulfilled the learning process was very high from the start, nevertheless problems with understanding the evaluation have decreased and the self learning and the students' autonomy is achieved at an earlier stage, also, the overall assignments quality has improved.

An assessment of the last three years of the implementation of this new teaching methodology is presented, pros and cons are evaluated and the methodology evolution is described.

This new methodology has proven to be effective because the students' interest, answered questions and "passion" for the biomaterials unit has been increasing over the years. Nevertheless this is an evolving methodology, much like the (biomaterials) area itself, and new and better routes will be found.

Keywords: biomaterials, engineering education, student-based learning.

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1. INTRODUCTION

As Biomedical engineering is a new degree, post-Bologna, created in Escola Superior de Estudos Industriais e de Gestão (ESEIG) only in 2006-2007, the Bologna paradigms (Bergen Communique, 2005; Bresciani, 2006; Hubball and Burt, 2004; Hubball and Gold, 2007) are applied in different ways. In fact, in the Biomaterials course there was never a teacher-based learning, nevertheless changes are occurring each year.
In student-based learning several approaches may be made ranging from self-evaluation, student-based research, teacher-based research, and other simpler methods such as simple assignments and worksheets to perform a continuous evaluation.
The Bologna paradigms affected not only the students but, and probably mostly, the teachers, once they were used to a teacher centred methodology. Thus, the fact that this degree was created in a so called post-bologna spirit does not necessary mean that teaching is actually 100% student-based, and in fact is far from that. Student-based learning takes more effort from the teacher and the effective teaching hours did not change towards this new time consuming way of teaching. Also, teachers are expected to be always available as new technologies like MSN, Facebook and other social networks are ready to be used.
Even though the degree is relatively recent, first year students enrolling in the degree have a 12 year handicap of an undergraduate teacher-based educational system. In fact, students are neither prepared nor motivated for single student-based learning.
Because of an increased pressure in the undergraduate educational system to produce results both in terms of grades and success rates, students show a more immature behaviour, lower knowledge and, overall, have a different (less positive) attitude towards university. This reflects in a more passive behaviour, lack of autonomy, lower self-confidence, but also no oral presentation, group organisation or debate skills.

The Biomedical Engineering degree in ESEIG had its first edition in October of 2006. As this is a wide spectra degree comprising areas of interest such as biology, medicine, materials science, electronics among others, it was developed in close collaboration with the Escola Superior de Tecnologias da Saúde do Porto (ESTSP). The degree's main goal was to educate biomedical engineers with a good background in medical machines to work in both maintenance and development.
As the biomedical engineering, biomaterials itself is a wide spectra course, where students have to have a previous knowledge in anatomy, physiology and be able to relate this matters to materials science and engineering.

2. CASE STUDY

The biomaterials course comprises the understanding of biomaterials properties and its influence in their applications, to understand and correctly apply the specific language of the biomaterials field and to describe the importance of the properties for the chosen application applying the acquired knowledge.
In order to accomplish the course's learning outcomes several approaches have been made and will be described and assessed.

1.1 Study group

The assessment will be presented for the last three years, even though the final results for the last year will only be available in July of 2010.
The student distribution is shown in table 1.

Students	2007/2008		2008/2009		2009/2010	
	1st time enrolment	2nd time enrolment	1st time enrolment	2nd time enrolment	1st time enrolment	2nd time enrolment
Female	9	- - -	10	1	15	- - -
Male	10	- - -	3	2	4	4
Total	19	- - -	13	3	19	4

Table 1 - Study group distribution.

Students' distribution evolved from the first year to the last being that the number of female students has clearly increased. It has also to be noticed that this last year has more enrolled students than in previous years, even though the number of first year enrolled students has been the same for the three years.

1.2. Methodology and Learning outcomes

The expected learning outcomes in the biomaterials module are:
- To be able to recognize and select biomaterials for specific applications.
- To understand biomaterials properties and its influence in their applications.
- To comprise the specific language of biomaterials field.
- To be able to describe by order of importance the main properties of a chosen application.
- To know the principal biomaterials references.
- To apply the acquired knowledge.

The methodology is student-based learning and the evaluation is supported in one major assignment and one project. Even though the support evaluation has been maintained there have been several changes in the way that both assignment and project have been undertaken over the three years, as follows:

1. On the first year, an interdisciplinary project based on a specific medical device was proposed involving all 2nd year courses. For Biomaterials the aim of this project was to learn about different medical devices, different biomaterials applications and corresponding interactions.
The results of this project were of difficult assessment and the learning outcomes were below the expectations. The references used were mainly internet based and the critical analysis to the device almost didn't exist.
The duration of the project, which was of two semesters (probably too long), and the involvement of many areas of expertise led the students to loose focus and lost themselves in the

extended amount of information they had gathered, and in fact they only started to have direct questions by the beginning of the 2nd semester. Furthermore, it was difficult to keep track of how the project was developing since the students approach to the teachers was extremely compartmented and they offered resistance to throw all that work behind them and start over, even when it was explained that they would fulfil the learning outcomes.

2. On the second year, the project involved only two courses, Biomaterials and Electromagnetism, the duration was of one semester and the expected learning outcomes were approximately the same. The project theme was different for each group, having different biomedical devices to study. The themes were chosen to be different than the ones of the previous year.
The results were easier to assess since a lot of constraints were drawn at the beginning of the project. This led to a more focused approach from the students and a more effective supervision from the involved teachers. In this project the learning outcomes were clearly overcome by most of the students, leaving only the scientific compliance and the actual critical analysis of the device behind.

In the first two years, several biomaterials were presented and sorted by each group as an assignment. The groups were expected to understand the field of applications of a specific biomaterial and be able to relate the biomaterial to the host location. In fact, the learning outcomes were completely shattered since most of the groups weren't able to research in trustworthy publications and shown little knowledge of the biomaterial and its field. Furthermore, their analysis was neither critical nor scientific. Nevertheless, the second year learning outcomes clearly surpassed the first year ones.

3. Although, last year project had surpassed initial expectations due to course rearrangements, this year the project is course specific, although with similar expectations, it has to be noticed that this year the project has only a semester duration and some adjustments are being made. And new and smaller assignment was given in order to overcome these problems. The assignment in the current year is a “review” article of one of three themes. This way the students are expected to, at the very least, learn how to search in the scientific field using scientific databases, articles and reference books. An in fact the results were extremely positive. The students had to work hard to use scientific literature, but the most important thing was they effectively recognized that it was a good effort that was asked.
The main theme is the same for all groups and within this theme the groups have to choose different applications and/or devices.
The learning outcomes expected from the assignment were that students learnt how to research in and about the biomaterials field in trustworthy publication.

In the first year since the expected learning outcomes weren't achieved with both the assignment and the project, the students’ knowledge on the biomaterials field was lower then expected in most cases.
To overcome this, in the second year, the evaluation comprised worksheets which were randomly given during classes in order to ensure that the students have wider range knowledge on the biomaterials field and don't just learn about the specific themes of both assignment and project.

Still, this was found to be insufficient and this year, in addition to worksheets, a percentage of the final grade is evaluated by simple tests.

3. RESULTS AND DISCUSSION

The results of first year reflected a hard working group of students with a high percentage of approved students but grades lower than expected.
The increase number of not approved students in the second year was a direct consequence of a more demanding evaluation combined with more supervised assignments.
Comparison of the approved and not approved ratios is shown in figure 1.

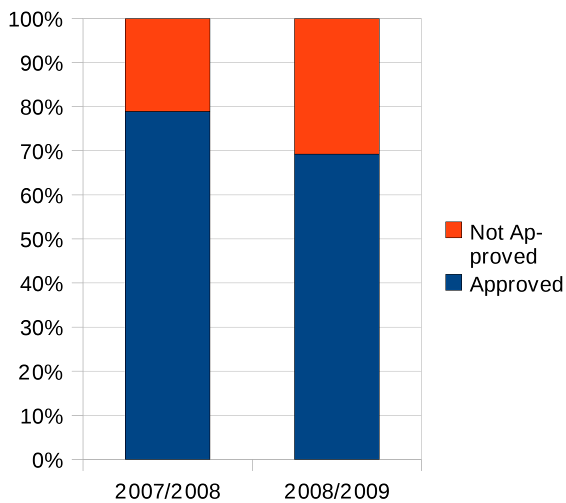

Figure 1 – Comparison of the approved and not approved ratio in the first 2 years.

To be noticed that the quality of both project and assignment were improved. This is shown clearly by the overall improvement in the grades in both project and assignment (Figure 2 and 3).

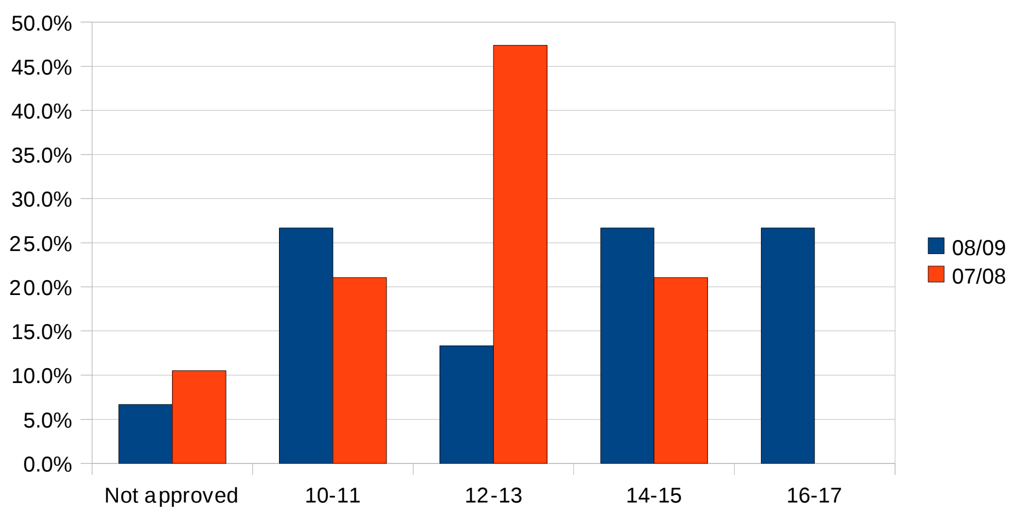

Figure 2 – Project grading in the first two years.

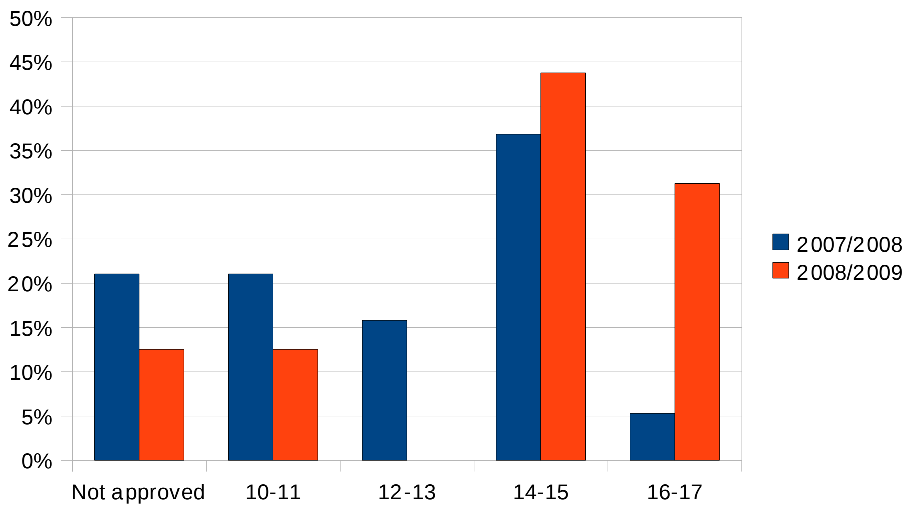

Figure 3 – Assignment grading in the first two years.

4. CONCLUSIONS

The evolution of the evaluations methodologies are clearly indicating that the students are effectively learning more, even though the percentage of students failing the course has increased.

It is also noticed, and although this is unrated that the enthusiasm and dedication of the students to the course was higher in the second year than in the first year and is expected to rise over the following years.

The expectations are high in what concerns this years' evaluation since better and better results in terms of learning outcomes are being achieved and students are showing increase knowledge in the biomaterials field.

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3rd International Symposium for Engineering Education, 2010
University College Cork, Ireland

ENGINEERING EDUCATION: NON-TRADITIONAL SPECIALISMS, AND THE SMART ECONOMY

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Keywords: Innovation, Engineering, Education, Economy, Environment, Entertainment.

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1. INTRODUCTION

Traditional technologically based industries significantly influenced engineering higher education programmes, since industrialisation. The recent appointment of the Irish minister Máire Geoghegan-Quinn to the European Commission for science, innovation and research indicates that non-traditional fields may play a more significant role in the 'new economy' of Ireland. In addition, the Irish government appointed the Innovation Taskforce Plans to sustain and enhance the 'Smart Economy' model in Ireland. Engineering education is key to areas such as the enhancement of energy supplies and communications infrastructure, as well as environmental technologies. There is a shift of emphasis from the construction traditional engineering industries to communications, energy and the environment.

The demand for graduates and their employment patterns may change significantly. Sustainable employment opportunities may exist in different forms, such as short to medium term contractual opportunities. Potential applicants, with an enthusiasm to study technological based programmes, may consider non-traditional industries, in which to apply their potential expertise, and are of more interest to them. Even at this time, opportunities are growing. One example is the television industry, where Ireland has made commitments to provide a digital, high definition service by 2012. Another example is the growth in technologies to support environmentally sustainable engineering schemes, for instance Building Energy Ratings (BERs).

There is a demand for engineering knowledge in areas that have not traditionally been associated, such as water, airflow, electronics, mechanics and agriculture, chemistry, food and biotechnologies.

These degrees may be made from existing modules from the traditional disciplines, and there is a danger that they may be hybrid degrees without sufficient focus on the overall objectives of the programmes, focussing on progression to employment or further specialist academic studies. The challenge is to develop and sustain academically strong degree programmes in these new sectors.

2. DRIVING FACTORS IN THE DEVELOPMENT OF NEW ENGINEERING DEGREES

2.1 Background

The worldwide economic downturn has made the Republic of Ireland, like many other countries; reflect on its strengths and weaknesses in the global marketplace. During the 'Celtic Tiger' years, the country began to gain a reputation for high-value expertise in technological areas such as software development and the biotechnology industry. It is believed that the expertise and structures are still in place for re-building the economy to include these sectors. In parallel with the economic downturn, there has been an increasing requirement for systems, products and services that reduce pollution and decrease the expenditure of energy resources. As well as this, the demand for information and communication technology (ICT) in terms of broadband and mobile services continues to increase at a high rate. The technological demands in the current decade will require a re-focusing of existing sectors, and the development of new ones.

2.2 Innovation Ireland and the Smart Economy

Over the past few years, the Irish government has published a number of reports outlining the steps in developing what it refers to as the 'Smart Economy' within the context of marketing Ireland as the 'innovation island' abroad. With reference to activities in Northern Ireland, the government has developed a strategy for revitalising the economy around the areas of:

- Environment;
- Energy;
- ICT.

It is not expected that these initiatives will, in isolation, reduce unemployment in the medium term to the average levels of the last decade, but will serve as a long term platform for sustainable growth and job creation over the next ten years or so. However, the success of such a plan depends on a number of requirements:

- Technological costs at low levels;
- People being available in Ireland with the correct skill-sets.

The educational and training needs for the smart economy are centred on the following disciplines:

- Engineering;
- Science;
- Business/Entrepreneurship.

2.3Energy and Environment

A number of initiatives are to be implemented, in order to develop the 'green economy' in Ireland (Department of Communications, Energy and Natural Resources, July 2009; Department of the Taoiseach, March 2010):

- Improved waste management systems, so that all waste can be put to useful purpose in dwellings, agriculture or energy consumption;
- Reduction of greenhouse gases;
- Development of 'green' goods and services;
- Use of ICT and advanced sensor technologies to monitor the environment;
- Water resources controlled more effectively using improved pipe construction and leak monitoring technologies.

The management of energy will also be a major part of the strategy to improve the environment via:

- New or emerging forms of energy source, such as geothermal, bio-waste/anaerobic digestion, solar, wind and ocean;
- Energy efficiency models in occupancies or dwellings to be enhanced to produce low or no carbon' output;
- Control and monitoring of existing resources using monitoring at system level and smart metering in the home;
- Use of innovatively efficient heating technologies, such as wood-chip and combined heat and power (CHP);
- Sustainable market development of 'clean' transport, for instance electric vehicles.

2.4 Information and Communication Technologies, and their Applications

The continued exponential projection in demand for ICT services has not abated during the recession. There is a growing need however for these services, amongst other things, to be used as a tool for economic and environmental sustenance. The market trend is towards the delivery of high speed, high quality audio-visual products and services to the individual, independently of location and to mitigate the need for travel. With this in mind, there are proposals to make Ireland a centre for the development of the necessary advanced technologies. These are summarised below (Department of Communications, Energy and Natural Resources, July 2009; Department of the Taoiseach, March 2010):

- A move away from traditional IP (Internet Protocol) to Packet Burst Networks to satisfy increased demand in on demand video, social networking, seamless mobile and fixed location (broadband) services;
- The development of Web 3.0 which will allow re-programming of web semantics by the user and dynamic procurement of bandwidth;
- High speed Metropolitan Area Networks (MANs);
- Virtual services for businesses and data mining corporations, such as 'cloud computing';

- The 'Exemplar Smart Network', which will on a trial basis encompass all facets of new ICT services, including 'green' applications such as environmental monitoring, before a full implementation in the next decade.

2.5 Government Institutions Involved in Developing the New Vision

The primary drivers at present are bodies such as:

- Department of the Taoiseach;
- Science Foundation Ireland (SFI);
- Sustainable Energy Ireland (SEI);
- Enterprise Ireland;
- Industrial Development Agency (IDA);
- Those organisations under the umbrella of the Programme for Research in Third Level Institutions (PRTLI), such as National Digital Research Centre (NDRC), Biometric Diagnostics Institute (BDI);
- Higher Education Institutions (HEIs) such as University of Dublin (Trinity College), NUI Dublin (UCD), UCC (Cork), UCG (Galway), IADT - Dun Laoghaire.

2.6 The Emerging Needs of Engineering Education

The primary drivers of the smart economy recognise the need for change in the way engineering education is approached in Ireland. It is no longer sufficient for graduates to be educated exclusively within a single discipline such as civil, mechanical and electronics engineering. These single disciplines will not be sufficient to meet the demands of the coming decades in themselves. Not only are interdisciplinary forms of engineering education needed, but that there is a rapidly changing scene in which new types of engineering will emerge as disciplines in their own right, for instance in the environmental and biotech areas. It is crucial that students gain the abilities to:

- Recognise the need for interdisciplinary approaches;
- Be better educated in fundamental engineering principles, independently of an engineering sector;
- Enhance life centred and product design skills;
- Improve their abilities to problem solve, think laterally, manage resources, be flexible in their approach and be prepared for the unexpected;
- Improve their business, self working and economic skills;
- Work closely with industry whilst being in education;
- Be prepared for employment in smaller groups with more autonomy but less job security, rather than be a 'small cog in the big wheel' of a 'blue chip' company;
- Integrate engineering approaches with the arts and humanities;
- Be prepared for lifelong learning.

These demands are significant on the student, however there is a need to re-image the purpose of engineering education and re-visit the principles of the discipline in the context of new requirements.

3. EXISTING ENGINEERING DEGREES APPLICABLE TO THE SMART ECONOMY

3.1 Overview

There are a number of engineering degree programme in the Republic of Ireland that can form the basis of engineering education in the smart economy. These programmes encompass the areas such as:

- Environmental/Energy;
- Biomedical;
- Audio-Visual/Multimedia.

3.2 Environmental/Energy

The Environmental Engineering BE Degree at NUI Galway (1) (intake of 10 students per year), has three main activity areas: waste and water management, industrial waste management and renewable energy/sustainable development. Within this, students are involved in projects related to particular problems such as industrial and domestic waste management and the design, installation and maintenance of ventilation, heating, lighting, acoustic and air pollution systems at domestic, public and industrial levels. There is a necessity for this programme however to be linked to the traditional discipline of civil/structural engineering rather than carve out a niche discipline in itself.

The M.Eng.Sc in Sustainable Energy at UCC (Cork) (2) specifically targets the area of improving the efficiency of energy consumption and developing renewable sources, using a variety of technologies.

3.3 Biomedical

The B.E. in Biomedical Engineering at NUI Galway (3) is described as an amalgam of electronic and mechanical engineering rather than a new discipline in its own right, although its links to biological science are implicitly clear. Surgery robotics and radiography applications are suggested as projects and applications, which is relevant in the smart economy to emerging markets such as non-invasive medical procedures and diagnostics.

3.4 Audi-Visual and Multimedia

The B.Eng in Audio-Visual Media Technology (AVMT) at IADT, Dun Laoghaire (4) provides engineering education in the area of electronic systems for the music, recording, radio, television and visual industries. Whilst not described as an engineering discipline in its own right, the area of audio-visual technologies is sustained through the recession by, for instance the entertainment sector. The emergence of high-speed multimedia networks and seamless broadband/mobile platforms supports the need for programmes such as this. The programme, whilst primarily focused on the technical context, also provides a strong creative flavour. AVMT was established in 1999 and has been a degree level programme since 2002, currently with approximately 100 students. It is an example of a programme in a non-standard discipline that has grown throughout the 'boom years' and continued to grow during the current economic period.

The School of Creative Technologies at IADT also provides the B.Sc in Multimedia Systems and Web Engineering (approximately 150 students), the M.Sc in Cyberpsychology (approximately 25 students) and the B.Sc (Hons) in Applied Psychology (which has a strong information technology element, with approximately 200 students). Such programmes have continued to grow rapidly since their inception in the late 1990s, and demonstrate an increasing relevance to the new economic models emerging in the state.

It is worth noting that one of the recommendations emerging from the Innovation Task Force (Department of the Taoiseach, March 2010) is the development of synergy between Arts/Humanities/Social Sciences and Science/Engineering/Technology. IADT is well placed to meet this recommendation.

3.5 Other Programmes

It is worth considering that there are other specialist branches of engineering that have been growing in the last decade and will continue to have a place in the smart economy. Examples are:

- Food Engineering: for instance the M.Sc.Eng programme at UCD;
- Fire Safety Engineering: for instance the B.Eng (Hons) programme at Letterkenny IT.

4. THE ADAPTATION OF ENGINEERING DEGREES TO THE SMART ECONOMY

It is clear that the existing engineering degrees have much further to go in adapting to the new economy. A number of recommendations as to how HEIs can achieve this are as follows:

- Critical and timely review of the emerging plans in the smart economy;
- Flexible provision of modules and programmes in order to match the new economic needs;
- Greater liaison with emerging industries, locally, nationally and internationally;
- Development of on-campus companies, with a long term view as well as incubation;
- HEI national committee to strategically advise on programmes, modules, projects and content in engineering education, so that all relevant areas of the smart economy are encompassed, as well as aid the viability of these programmes in lean monetary times;

- A fundamental review of the engineering discipline, as taught at third and fourth levels, so that the skills and competences of graduates will be flexible enough to meet the new demands;
- Active promotion of engineering education in the smart economy.

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THE ROLE OF INDUSTRY IN GUIDING THE PEDAGOGY OF CHEMICAL ENGINEERING DESIGN

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Today's chemical engineering graduates work in a diverse range of industries many that are operating at the innovation, technological and business frontiers. Educating graduates with modern, relevant, design skills requires careful curriculum development and critically should combine input and feedback from industry.

Curriculum development is explored based on the Henley report (2006). This report identifies at least five broad areas of changes which it is felt will have a major impact on engineering:

1. Providing customer solutions, with the need to being focused on all of the customer's requirements and in doing whatever is necessary to solve them.
2. Increasing complexity of the technological domain leading to manufacturing incorporating numerous different technologies across different disciplines into a single product.
3. Globalization and recognition that even at the highest skill levels engineers are subject to international market competition.
4. Sustainability, emphasizing ecoefficiency, corporate social responsibility and operating these principles within the markets.
5. Innovation and creativity as forces which will differentiate products in an increasingly competitive marketplace.

A review of the current status of chemical engineering practice and education is presented alongside the drivers for educational change. Using questionnaires, opinions are compiled from students, lecturers and industry professionals evaluating the design teaching environment including the appropriate mix of defining and enabling skills.

The information and data collected provides a valuable insight into the development of chemical engineering design teaching. A future curriculum development scenario is presented for the enhanced teaching of plant & process design.

Keywords; design, education, curriculum, industry, questionnaire.

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1. INTRODUCTION

Chemical engineers are responsible for the conception, design and operation of processes for the production, transformation and transportation of materials. Design can be defined as the creative process whereby we generate ideas and then translate them into equipment and processes for producing new materials or for upgrading the value of existing materials. The importance of design, R&D and production activities for engineering graduates can be seen from figure 1. It is also evident from figure 1., that engineering graduates are assigned across a very wide spread of duties. This is principally due to the skill of chemical engineers as technology integrators with an ability to provide scientific/engineering solutions to range of customer problems.

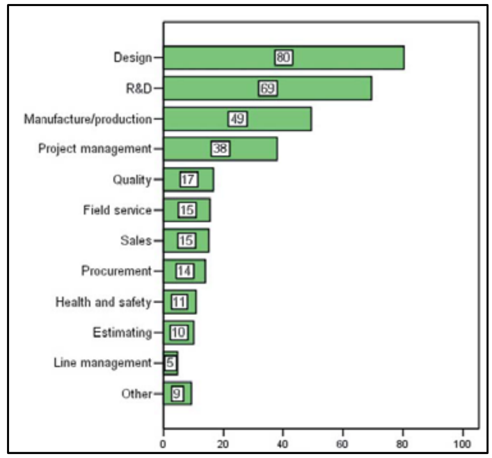

Figure 1. Graduate roles within two years of recruitment. (Royal Academy of Engineering , 2006)

The nature and type of design activities that engineers are engaged in is not fixed. Increasing worldwide competition is mandating major changes in the way plants are to be designed. As a result, we are witnessing dramatic new developments that go beyond “traditional” chemical engineering. New equipment technologies and novel techniques are emerging that potentially could transform our concept of chemical plants and process engineering, leading to compact, safe, energy efficient, environment-friendly, flexible processes and plants. (Pamuntjak, 2006). New commercial opportunities in biotechnology, pharmaceuticals, electronic device fabrication, sustainable technologies and environmental engineering are increasingly important sectors for chemical engineering input.

The question arises that with all of this change, is academia providing appropriate teaching to meet the expectations of graduate employers. According to (Shinksey, 2002) the industrial-academic gap in the specific area of process control has been a persistent impediment in design education. Shinksey states that the papers on process control presented at the American Automatic Control Conference in the year 2000 showed little if any improvement in the direction of industrial practice from the 1965 version of its predecessor, the Joint Automatic Control Conference. “No progress in 35 years”!

2. THE CURRENT STATUS OF ENGINEERING EDUCATION

Typical design activities undertaken by students include; process selection and design, safety reviews, development of piping and instrumentation diagrams (P&IDs), development of plant layout, estimation of operating costs, and equipment design.

To be able to carry out design activities, the chemical engineer requires a complete and quantitative understanding of both the engineering and scientific principles underlying the technologies employed. The Chemical engineering courses are built on a foundation in the sciences of chemistry, physics and increasingly nowadays biology, engineering knowledge is developed through the study of mathematics, material and energy balances, thermodynamics, fluid mechanics, energy and mass transfer, separations technologies, chemical reaction kinetics and reactor design, plant and process design..

Education as currently practiced involves the “batch” processing of students, with the obvious desirable attribute of creating uniform patterns of thinking and knowledge in future graduates. Batch processing is necessary to facilitate the task of educating large numbers of functionally equivalent units (4 year degree cycle).

The assumption that batch processing is still the only way to produce educated graduates has been rendered obsolete by advances in information communication technology (ICT) that make personalised education technically possible. (Allenby, 2009).

Current educational practice involves a wide range of activities; classroom teaching (chalk and talk), laboratory exercises, continuous assessment both open and closed book, group and individual tasks final examination. Most of these activities are batch in nature and very few are found in any real employment situation. Even much touted teaching tools such as “Blackboard” bare little relevance to life outside of college. The challenge to educators is to create a learning environment which is in harmony to the graduate’s career experiences.

3. DRIVERS FOR EDUCATIONAL CHANGE

Developments in the world of chemical engineering such as cutting edge technologies, business acumen and market expertise are instigating major changes in the skills and competencies required by engineers. According to (Fauve et al., 2008) these rapid changes of chemical industry, together with the emergence of new scientific and teaching tools, pose a formidable challenge to chemical engineering teaching. The evolution of existing curricula demands the identification of a subtle balance among competing constraints:

New developments go well beyond the boundaries of “traditional” chemical engineering and have the potential to transform our concept of process engineering. These changes are leading to compact, safe, energy efficient, environment-friendly, flexible processes and plants. The new paradigm for engineering graduates is to be capable of tackling the major emerging issues:-

- Customer Based Solutions
- Complexity of the technical domain
- Globalisation
- Sustainability
- Innovation & Creativity

Even in the current recessionary times world markets are expanding. With the immergence of both China and India as major industrial powerhouses almost 2 billion people are being added to the marketplace. This is a totally different world for young graduate engineers and will not only affect how they are educated but also what they are educated in. Education must focus no longer simply on content, but also on context.

Global competition places enormous market pressures on companies to bring their innovations to market faster than competitors. This is likely to change how we think about education. Specifically, there will be greater interest placed upon:-

- Solving multi-dimensional and multi-disciplinary problems
- Integrating economics consistently into the problem-solving context;
- Acquiring skills related to project management and team dynamics;

- Reintegrating engineering with invention and creativity
- Effective oral and written communications.

Put very simply, “process engineering” skills have never been more important to the global workforce. The ability to convert an idea into a salable product, at the fastest time, lowest cost, and with the least environmental and safety impact, is of critical important to today’s company above all else. (Roman , 2009)

Engineering progress should also be viewed within the context of global environmental constraints. The decisions graduating engineers make in their work will be informed by the concepts, values and methods of analysis passed to them during their educational career. Degree curricula need to ensure that environmental and sustainability concepts are embedded throughout a student's entire education.

The past decade has witnessed international interest in incorporating the skills, attitudes and concepts of sustainability into undergraduate university courses across a range of disciplines (Wright, 2002). The Institution of Chemical Engineers (ChemE) CEO, David Brown has commented: “Students are increasingly recognising the value of a chemical engineering degree and the doors it can open professionally.” And added “The scientists and engineers of tomorrow will be responsible for finding solutions to many of the problems facing our planet. I passionately believe that the process industries have a key role to play in our transition to a more sustainable society.”

4. QUESTIONNAIRE

A questionnaire was developed and sent out to academia and industry to assess the current opinion on design teaching. The drivers for educational change already highlighted, formed the backdrop for this questionnaire. The analysis was developed using “Survey Monkey” and a link to the online questionnaire was distributed via e-mail. In total 71 academics, students and industry based engineers responded. The questionnaire was a combination of open questions and multiple choices.

Where the correspondent was required to choose an option these were ranked in the following order:- Not Relevant (1) -Relevant (2)- Important (3)- Very Important (4)-Vital (5)

THE QUESTIONS POSED WERE AS FOLLOWS:-		
I.	Are you a student, academic or industry based engineer	i. Student ii. Academic iii. Industry Based Engineer
II.	In your opinion, what do you consider to be most important aspect in the teaching of chemical engineering design?	Open Answer
III.	In your opinion, what do you consider to be the greatest weaknesses in the teaching of chemical engineering design?	Open Answer
IV.	In your opinion does the teaching of chemical engineering design currently address the changing chemical engineering work environment in terms of technology and business trends?	Open Answer
V.	What importance would you give the following for creating a good learning environment for engineering design	i. Use of multimedia (TV/ VIDEO/ Interactive White Boards) ii. Dedicated student design office iii. Availability and use of process simulation and modeling software iv. Structured group learning v. Individual task responsibility vi. Skills related to project management and team dynamics vii. Integrating economics into the problem solving context

		viii.	Integrating sustainability into the problem solving context
		ix.	Effective oral and written communications
		x.	Other
6.	Over the next 10 years how relevant do you think each of the following employment/ technology sectors will for the design skills of Chemical Engineering graduates?	i.	Pharmaceutical
		ii.	Bulk Chemical
		iii.	Biotechnology
		iv.	Nuclear
		v.	Energy (including domestic / biofuels)
		vi.	Research / Innovation Startup Companies
		vii.	Consumer and Food Products
		viii.	Other
7.	How do you think universities might better integrate the teaching of design with industry:	ix.	Peer Mentoring with Industry Based Engineer
		x.	Industrial Site Visits
		xi.	Guest Lectures from Industry
		xii.	Real World Industrial Case Studies
		xiii.	Design Focus prior to Industrial Placement
		xiv.	Other
8.	What skills do to think industry based engineers can bring to the study of engineering design:	xv.	Theoretical Understanding
		xvi.	Practical Application
		xvii.	Creativity & Innovation
		xviii.	Team Working Business & Management Skills
		xix.	Ethics & Professionalism
		xx.	Entrepreneurship
		xxi.	Other
9.	In the assessment of student work how would you rate the following:	i.	Academic supervisor assessment & marking
		ii.	Industrial supervisor assessment & marking
		iii.	Combined academic/ industry supervisor assessment & marking
		iv.	Student peer marking (students grade each others work)
			Student peer assessment (students critique each others work, supervisor then grades the work)
		vi.	No assessment & marking
		vii.	Open Book Exams or Design Exercise
		viii.	Closed Book Exam or Design Exercise
		ix.	Other
10.	If there was one thing you could change to improve the teaching of chemical engineering design what would it be?	Open Answer	

Table 1. The online questionnaire / survey

4.1 Questionnaire analysis

The questionnaire was completed by 48% industry based engineers, 36% students and 16% academics. In general the student and industry based responses were most similar. This was an interesting and unexpected linkage. The strong underlying theme with respect to identifying the most important aspect in the teaching of chemical engineering design was to incorporate more active participation of industry in education. When considering what was the greatest weakness with regards to engineering design education; students largely identified the gap between theory and practice, Industry based engineers also identified

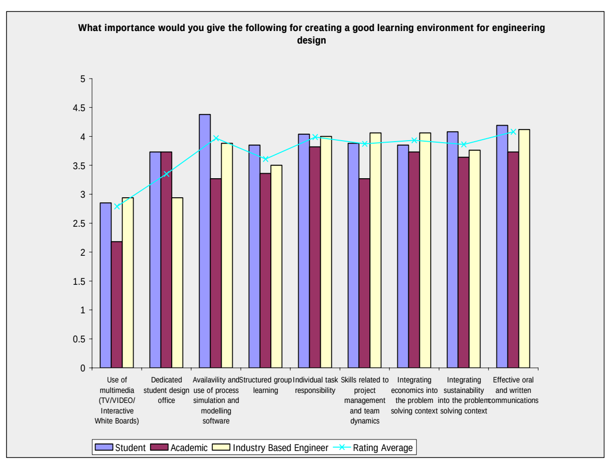

Figure 2. Factors contributing to a good learning environment (1 = not relevant 5 = vital)

issues such as the teaching of outdated or irrelevant design material. Academics highlighted issues relating to the teaching environment such as rote learning being rewarded. The opinion with respect to whether the current engineering design education met the technology and business trend is best illustrated by one of the more insightful student answers declared, "*I don't know- but the fact that I don't know shows a weakness in the teaching of chemical engineering design. Any student should be aware of the business and technology trends in the subject being taught*" Figure 2. shows the various factors contributing to a good learning environment, students identified process simulation and modeling software as a key contributing factor, presumably as they view this as a "real world technique" but also because such software enables them to handle complex multivariate problems. A dedicated design office was favored by academic, with industry valuing management, economic and communication skills. When examining the relevance of future technologies, figure 3. shows that respondents considered biotechnology energy and R&D as key strategic development areas. In figure 4 the role of assessment is examined, student's preferences were for joint industry/academic or industry only assessment followed by academic assessment. The academic response on the other hand strongly favoured the standard academic assessment for student work. Figure 5 shows a preference across all sectors for more real world examples as am means of integrating industry and academia.Finally the questionnaire posed the question *"If there was one thing you could change to improve the teaching of chemical engineering design what would it be?"* and table 2 shows a synopsis of the replies received, indicating a range of options which could be considered.

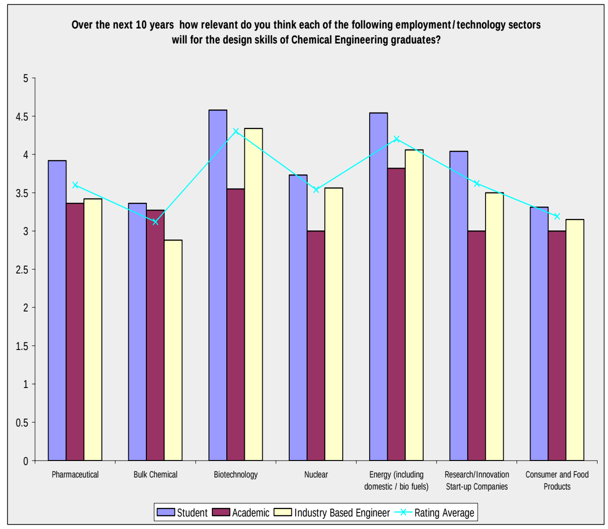

Figure 3. Relative importance of future technology sectors (1 = not relevant 5 = vital, Blue)

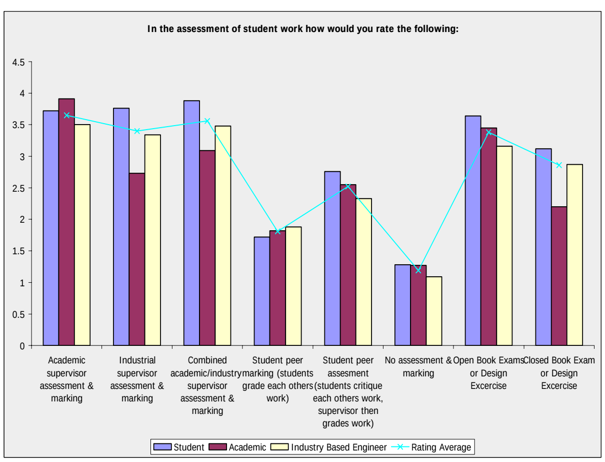

Figure 4. Evaluation of student assessment techniques (1 = not relevant 5 = vital)

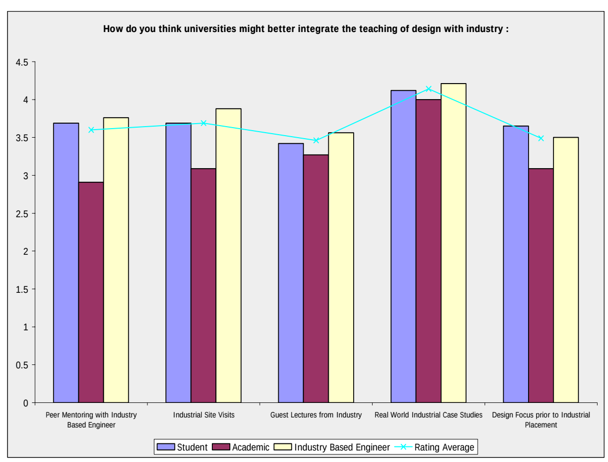

Figure 5. Integration of the teaching of design with industry (1 = not relevant 5 = vital)

IF THERE WAS ONE THING YOU COULD CHANGE TO IMPROVE THE TEACHING OF CHEMICAL ENGINEERING DESIGN WHAT WOULD IT BE?
– Real industrial case studies with greater contact between students and industry – 5 year degree course with two 6 month industrial placements – feedback should be given on assignments handed up- where you went wrong, how to improve – Smaller peer assisted tutorials with hands on help for designing specific parts of projects – Exams should be less abstract – More hands work on in earlier years of degree – More emphasis on what can go wrong with machinery/ processes and how they are dealt with. Not catastrophic problems, but ones that happen on a regular basis and dealt with as such – More notes should be put on blackboard

Table 2. Factors influencing the improvement of the teaching of chemical engineering design compiled from all correspondents)

5. FUTURE CURRICULUM DEVELOPMENT SENARIO

Any curriculum change should according to (Favre et al.,2008) retain the core identity of a chemical engineer. The curriculum should enable engineers to effectively, communicate and work with chemists, physicists, biologists, and find solutions to problems “from beaker to plant”. Curriculum development which is guided by practicing chemical engineers providing; case studies/technical expertise consultation/direct student instruction is identified in the survey as desirable and could include some or all of the following concepts:-

– Introduce “current industry design practice” workshops taught by accomplished practicing engineers. This could be achieved with evening classes or alternatively use retired engineers for daytime workshops.
– Consult with industry based engineers to provide regular team-based multi-dimensional, multi-disciplinary “real industry world” design challenges.
– Discuss design management and the economics of decision-making in the curriculum with practicing project engineers. Engineers need excellent business/administration skills;
– Introduce technical innovation startup companies / engineering entrepreneurs presentations to design courses. Students need to understand how an idea becomes a new product, as well as how to manage and lead this type of project.
– Incorporate structured role-play in team-based design challenges as an important way for students to learn how to be followers as well as project mangers. Students should understand the crucial relationship between management and leadership.
– Give students more responsibility with some amount of peers assessment and grading. Discuss with industry based engineers how they assess/critique their own designs.
– Include wider geo-political perspectives in the same context as enterprise innovation and sustainability.

6. CONCLUSION

The evidence gathered from the questionnaire suggests that the "design education" students currently receive has still some distance to go to better reflect graduate practice and experience. The survey indicates that industry has a fundamental role in education; in providing real world case studies and in giving academia access to contemporary thinking on technical and business challenges. The unfortunate observation of Shinksey nearly ten years ago "no progress in 35 years" is to a certain degree, reaffirmed in this survey. The possibility exists in this modern era of dynamic change, digital communications and information dense environments of unprecedented complexity design; to break free from anachronistic pedagogical models. Opportunities for the active contribution of industry based engineers and experiences have been suggested in the curriculum development scenarios. If nothing else the information sharing interchange would be hugely beneficial to course development.

Academic survey responses generally placed less emphasis on nearly all areas in comparison to both the industry and student replies, this perhaps reflects the unique perspective of the educator, but also could indicate a certain level of isolation from, employment realities facing both students and graduates.

The word engineer is from the French word 'ingénieur', which itself is derived from the classical Latin word 'ingenium', which means 'ability' or 'genius'. This survey has indicated that there is a significant role for industry in guiding the pedagogy of engineering design, and that much of this potential remains untapped. Increased involvement of industry based engineering can only strengthen the "ability and genius" in education.

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INCORPORATING A 5S STRUCTURED APPROACH TO THE PLANNING AND DELIVERING OF A FINAL YEAR DESIGN PROJECT

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The final year design project is a capstone, facilitating students in integrating all of their chemical engineering skills to delivering a specific body of work. In addition to the technical and scientific proficiency demanded in the development of the design solutions, students also need to address environmental and societal issues, provide marketing, business plans and analyse the economic feasibility of the investment. The ability for students to effectively cope with this multivariate task is key to a successful outcome.

The 5S management concept is originally associated with Kaizen a Japanese philosophy for achieving continuous improvement in production. A key concept of the 5S system is to empower those involved and thus embedding a real sense of project ownership. The value of students utilising such a structured approach to the formulation and development of their design project is explored. By placing their core project objective in the center and positioning the 5S engineering paradigms around this purpose will provide a methodology to continually reassess and improve the project as it progresses. In this case, however, the meaning of the "s" is different. Thus we see 5 key engineering concepts with the design goal paradigm:-

1.	**Sustainability**	The challenges faced are really opportunities
2.	**Safety:**	Embedding safety both in plant and product
3.	**Soft Skills:**	Innovation and leadership driving success
4.	**Simulation**	Facilitating technology transfer and process fitting.
5.	**Sectors**	Changing sectors of business operation for engineering

The incorporation of the 5S as a vehicle to promote the modern requirements of chemical engineering in design is illustrated with the experience of the design project course of the chemical engineering degree at UCC.

Keywords; 5S, design project, kaizen, sustainability, management.

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1. INTRODUCTION

The future global employment environment will be dominated by a need to redefine what makes engineering and technology graduates successful. Traditionally, success has been defined by having “intelligent” graduates who have completed a rigorous college course that stresses problem solving and mastery of significant amounts of technical information (Roman, 2009). Design is where engineers can best display their technical mastery, their creativity and capacity for using new concepts and technologies. It will be in the teaching and application of design skills where this redefinition of the successful graduate will be most evident.

In modern business, people and organisations consider the ways in which products or services that they deliver to customers can be continuously improved. Kaizen and the 5S methodology is technique commonly used in industry to address the need for continuous improvement. The need also exists for universities to address the ways in which they can better serve their customers, both students and eventually the employers of graduates. Universities are of their very nature open and receptive to change but perhaps sometimes lack the mechanisms to build responsiveness to ongoing changes in customer’s wants and needs into their teaching.

Research into design thinking has not yet comprehensively answered questions regarding how design is done, and accordingly, there is no consensus on how it should be taught (Dym et al.,2005). The door is still open to teaching development and one possibility would be to adapt tools commonly used in an industrial setting to streamline and provide order to complex processes, namely Kaizen.

Kaizen is a Japanese word that means: “change for the better,” and is typically interpreted as implying a process of “continuous improvement.” The phrase “change for the better” implies any change that results in improvement, which could be related to quality or other factors that customers judge to be of value, such as innovation, ease of use, on-time delivery, durability, low cost, etc. (Zimmerman, 1991). To take the concept of performance to its ultimate level of simplicity, kaizen offers the "5S" steps of good housekeeping:

- **Sort:** Separate out all that is unnecessary and eliminate it.
- **Straighten:** Put essential things in order accessed.
- **Scrub:** Clean everything; tools and workplaces
- **Systematise**: Make cleaning and checking routine.
- **Standardise**: Make the previous four steps into one standard process

The Kaizen 5S process could be viewed ‘merely as housekeeping process’ but it does have a much wider potential to provide a systems approach to issues. The 5S can provide a simple structure to manage very complex tasks. The original 5S concept can be used as an allegory to an improvement of the design teaching/learning process. To achieve this one needs to identify a set of elements that do not constitute the basis of the process itself, but that provide innovative features whereby the process is improved. An extension of this concept to the final year design project is to identify 5s's that will provide step changes for improvement:-

–	**Sustainability**	The challenges faced are really opportunities
–	**Safety:**	Embedding safety both in plant and product
–	**Soft Skills:**	Innovation and leadership driving success
–	**Simulation**	Facilitating technology transfer and process fitting.
–	**Sectors**	Changing sectors of engineering business

Chemical Engineers design and operate facilities capable of manufacturing everything from baseline commodity production to complex medicines for human consumption. Most recently they have been to the forefront in the development of technologies capable of meeting major environmental issues such as carbon capture technologies. Chemical engineering design can be defined as the creation of a process and manufacturing plant to manufacture a specific material (originally this would have overwhelmingly meant chemical synthesis processes; more recently bioprocesses and emerging technologies are also considered). The range of chemical engineering designs is virtually limitless and is intrinsically linked to the modern societal needs. Final year design projects therefore provide students with their primary experience of the real world technical and political complexities.

Chemical engineering courses require students to learn and be capable of applying design skills. In the final year of the degree programme a major design project (10 ECTS is a typical requirement) is undertaken. The project reflects typical career based activities and is a team based task, usually in groups of between 3 to 6 persons, but with a strong and identifiable element of individual input and responsibility. The design project provides the ideal platform for students to acquire high level skills valued by employers and society. The Royal Academy of Engineering (2007) have identified that businesses now seek engineers with abilities and attributes in two broad areas:-

- Technical understanding
- Enabling skills.

The former comprises: a sound knowledge of disciplinary fundamentals; a strong grasp of mathematics; creativity and innovation; together with the ability to apply theory in practice. The latter is the set of abilities that enable engineers to work effectively in a business environment: communication skills; team working skills; and business awareness of the implications of engineering decisions and investments.

In addressing these goals students operate in uncharted territory, for each group the immersion into the world of chemical engineering design involves meeting multiple and interacting challenges, operating effectively as a group, and tackling not just the technical requirements of the design but also addressing the wider societal issues.

It is suggested by the IChemE (2009) that by the completion of their chemical engineering degree graduates must know and understand the importance of identifying the objectives and context of the design in terms of:

- The business requirements
- The technical requirements
- Sustainable development

– Safety, health and environmental issues
– Appreciation of public perception and concerns

2. THE APPLICATION OF 5S THINKING TO THE DESIGN PROJECT

Teaching design is not a singular task. As has been illustrated earlier the skill sets required and applied to chemical design are many and varied. Throughout the degree the student will have met a range of engineering topics in thermodynamics, heat and mass transfer, process control, among others, which will form the backbone of their design ability. It can be seen therefore that it is important to ensure that all teaching staff are part of the "design teaching philosophy" of the department or degree course.

However the final year design project is a definable and separate piece of work within the degree programme which is supported, supervised and graded. It is proper that this support would facilitate students in tackling this challenging and open-ended task by providing a structured approach to continuous improvement.

The notion of continuous improvement applies to the course (year on year module improvement) and to the specific project (month on month design improvement).

As with the application of the 5S in an industrial setting students engaging in a design task are encouraged to continually structure and order their project through the perspective of the 5S of sustainability, safety, soft skills, simulations and sectors.

2.1 Sustainability

"The challenges faced are really opportunities"

The notion of sustainability has been around for twenty years or more, it is not a tightly defined concept and means different things to different people. Recent climate change debates have given a renewed impetus to the drive for responsible developments which address the needs of triple bottom line of, social, environmental and economic. Table 1 shows the seven key areas that sustainable designs and products should address as identified by World Business Council for Sustainable Development (2001).

KEY AREAS FOR SUSTAINABLE DESIGN	IMPLICATION
1. Innovate	Novel technical and social resources – new ways to improve lives while boosting business
2. Practice eco-efficiency	Economic benefit and environmental performance
3. Move to partnerships for progress (move away from stakeholder dialogues)	Shared understanding, aligned action and social inclusion
4. Provide and inform consumer choice	A different type of demand by enhancing appreciation for values that support sustainability
5. Improve market framework conditions	A stable, corruption free, socio-economic framework that facilitates positive change
6. Establish the worth of Earth	Environmental conservation and promotion of resource efficiency
7. Make the markets work for everyone	Economic benefit and social cohesion

Table 1. Key areas of consideration for sustainable design

2.2 Safety

"Embedding safety both in plant and product"

Design is that activity where the physical artefact or a part of it, which is under design, is not currently in existence, but will be in the future. This has major implications from a safety perspective, which has been recognised in chemical engineering education for some time now. It is important that students be introduced to the concept of inherently safer design and that they realize that safety in plant operation must be considered right at the start of the design study. Process safety must be taught in a rigorous, stimulating way by staff of appropriate experience, and students now have in Design Project the possibility to practice and apply the appropriate tools (Harvey 1984).

2.3 Soft skills

"Innovation and leadership driving success"

Soft or transferable skills range from communication and team work right across to leadership and innovation. Soft skills are often critical attributes required to bridge various technical and disciplinary boundaries. As an example we see the interaction between technical expertise and its commercial exploitation at best as a fragile one. (Gupta & Wilemon,1990) suggested that products, which met their development budget but had experienced delayed launch dates generated substantially less profit than those that exceed their budget but come to market on time. In engineering, the project team is the most common form of organisation. Project teams are frequently multidisciplinary in makeup. Making project teams work efficiently and being an effective contributor are career building skills (Hall, 1990).

2.4 Simulation

"Facilitating technology transfer and process fitting"

The fact that a design outcome has yet to be built affords the possibility of representing it conceptually. The need for conceptualization in the form of a prescriptive model of some kind is obvious when the issues met are complex and design is done in an organisation. The use of process simulation is widespread. Currently, over 800 universities worldwide use the same AspenTech software as global industrial leaders including: (AspenTech, 2010)

- Top 30 petroleum companies
- Top 50 chemical companies
- 14 of the top 15 pharmaceutical companies
- 14 of the top of 16 engineering and construction companies

Process simulation is achieved using software programs designed to model process plants. Simulation is especially important in modeling systems that do not yet exist, or that would be too expensive to 'play' with. While traditionally process simulation has been associated with the large industrial plants in recent years, process simulation has been adapted by a wide range of smaller, less traditional process industries.

An example, of the versatility of process simulation and the interaction across the 5S paradigm is given by (Stefanis et al., 1995) in the study for a vinyl chloride monomer (VCM) production process. In this study the process was optimised with consideration of the global production chain. The study found that when the process was optimised for one type of pollution it often resulted in the generation of higher values of another type. Minimizing air pollution may in fact increase water pollution. When optimisation was completed for several types of pollution simultaneously, lower overall environmental impacts were achieved in the global system, not the individual system. The study also revealed that beyond a threshold value of abatement overall environmental impact could increase due to the trade-off in the impact associated with inputs versus outputs.

2.5 Sectors

"Changing sectors of business operation for engineering"

Today the chemical and related industries are in a period of rapid evolution much of it due to the unprecedented demands and constraints, stemming from public concern over environmental and safety issues.

As a consequence many of the chemical products of today and tomorrow do not have much in common with those of twenty years ago, the portfolio of skills and technical knowledge required by chemical engineers has also been changing rapidly. Chemical engineering and design practice must address this new reality.

Consider that over 14 million different molecular compounds could be synthesized in 2005. About 100,000 can be found on the market today, most of them are deliberately conceived, designed, synthesized and manufactured to meet a human need, to test an idea or to satisfy a quest for knowledge.

The development of combinatory chemical synthesis with the use of nano- and micro technology is an example of just one current industry trend. The new keywords associated with modern chemistry in the 21st century are life sciences, information and communication sciences, and instrumentation (Charpentier, 2009).

The student of today will graduate into a very dynamic employment sector, where it is increasingly difficult to be first on the market with an innovative product, and thus speeding up the product/process design development is of paramount importance. Some of the other emerging chemical engineering technological sectors include:

- BioEnergy / Green Engineering
- Biotechnology / Bioproducts,
- Clean Coal Technology / CO_2 Sequestration
- Energy / Environment
- Food Processing
- Green Technologies / Process Intensification

3. THE 5S IN THE DESIGN PROJECT OF THE BE PROCESS & CHEMICAL ENGINEERING AT UCC

The incorporation of the 5s into the teaching and learning philosophy of the final year capstone PE4010 Design Project of the BE Process & Chemical Engineering, UCC, is outlined next. In the design project students deliver one group report, and also individual design memos, which contain a detailed design of one unit operation. The real benefit of this systems approach for the students is the ability to periodically perform a 5S sweep across their design work, to in effect "clean, refocus and reorganise". Thus the somewhat daunting and amorphous task of design is rendered more achievable to the uninitiated. Table 2 illustrated the application of the 5S to the design project in UCC.

5S - STEPS	FEATURES OF DESIGN PROJECT
Sustainability	Student consider holistic design solutions and must present and defend the sustainability issues of the final design and business proposed. Is the process sustainable? If not, where are the elements of unsustainability, how could they be improved or eliminated, and what would be the cost of doing so? The objective of the "sustainability statement" is to make students reflect on the unsustainable nature that many processes do have, and assess why it is so, what are the costs and consequences of change, in anticipation for times when a much stronger emphasis on sustainability *versus* immediate costs will need to be proposed.
Safety	At a fundamental level both HAZOPs and Hazids are required, for the design memos that each student performs individually, and for the overall manufacturing process and plant laid out. This requires students to reflect on the operability and safe functioning of the various units or processes. At a more expansive level students will need to consider total lifecycle issues with respect to product plant and waste streams to insure that safety is not just a one dimensional facet of design, and integrating safety and sustainability.
Soft skills	Design begins by exploring the issues of organisational behaviour that underpin effective team work (teams and roles, personality traits, conflict orientation). Students must organise the team, plan the work, and keep track of the project evolution with recordings of meeting minutes. The team dynamics are an element of the assessment of the team's performance. The final project is presented also orally, to assist the strengthening of communication skills incorporated throughout the whole degree.
Simulation	Students are required to integrate the use of professional design software (AspenTech, or SuperPro) into their design methodologies. The design of individual unit operations (in the design memos) and of the entire process should be optimised. Students should apply the experimental design and data analysis concepts the learned elsewhere to establish the optimum combination of design choices.
Sectors	The topics of the Design Projects are not limited to conventional, traditional petrochemical products. Most are pharmaceuticals /biopharmaceuticals or innovative processes such as in the bioenergy area. These design areas are often driven by social and political change requiring cogeneration of business development plants alongside the advancement of technical issues. With novel designs much of the technical information on the specific chemicals at stake may not be easy to find, and students must consider a reasonable approach to overcome this lack of data. Many processes must also be developed out of patent descriptions, which leads students to consider with their own knowledge and creativity how a synthesis process described in a lab can be turned into an industrial scale process.

Table 2. Application the 5S structured design methodology to design projects

4. CONCLUSION

Chemical engineers are without any doubt valued as excellent problem solvers, equipped with the skills to do rigorous mathematical analysis required for design, modeling and simulation of multivariate systems. Engineering education has trained students in a systems thinking methodology, as a consequence students/graduates should have the skills and capacity of tackling both multistage and multidisciplinary tasks. These are the very engineering acumens required by society to face the global challenges of a changing social, technological and commercial dynamic. It is appropriate that students are given the opportunity to learn their engineering design skills in a measured and consistent fashion. It is also appropriate that academia be prepared to adopt practices from different cultures and professions. The 5S structured approach to engineering design will without any doubt strengthen student learning and practice. In conclusion we can see that value of organisation and continuous improvement in education is as true now as in the distant past, taking the words of the Roman philosopher Lucius Annaeus Seneca, "No man was ever wise by chance".

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CURRICULUM DESIGN OF MECHANICAL ENGINEERING IN A DEVELOPING COUNTRY

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Abstract: The curriculum and syllabi in Engineering Education is dynamic as it shifts with societal requirements as well as student inputs. The present paper deals with a study of the historical data of the changes in basic components of mechanical engineering curriculum in a developing country - the case study being that of Mechanical Engineering Department, Jadavpur University for last 50 years. Jadavpur University is presently ranked amongst the top 6 science and engineering institutes in India with respect to research ranking (based on Scopus data) or accreditation agency ranking (institution based). The study shows, that lack of local industrial input has been a predominant feature in changing the percentage of basic components in engineering curriculum and needs to be addressed even though technology is considered to be borderless now.

In the GATS regime, homogenization of engineering education is being attempted through Washington Accord, Bologna treaty etc. India is a signatory to the Washington Accord. Accordingly, AICTE, which is implementing this in India have formulated a curricular framework which includes 10-15% Basic Sciences, 15-17.5% Engineering Sciences, 10-15% Humanities social sciences and Management, Professional core 22.5-27.5%, Electives 19.5-25%, Seminar and Industrial Training 2.5-5% and Project 5-12.5%. However, author is of the opinion that even with cross-border movement of engineers, the national requirements should get priority in framing curriculum and syllabi of that country, which this work highlights with respect to one of top universities and research institutions of India, Jadavpur University. Such studies can give an insight into academic ranking and strength of the same department in various institutes.

Keywords: Curriculum Design, Engineering, Developing Country

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1. INTRODUCTION

Curriculum is the formal mechanism through which intended educational aims are achieved. This formal mechanism includes two prime factors: learning and instruction. The curriculum incorporates the social, cultural and even political background of the programme of a course. It is defined by a set of subjects taught in a particular course with hierarchical structure (linked), duration (periods and credits), % of theory and practical in overall course structure, evaluation procedure and standards. Curriculum issues are inseparably linked to current thinking and action on educational concerns and reforms around the world. Syllabus forms the core of curriculum. They are the components of the curriculum.

2. CURRICULUM DEVELOPMENT

Curriculum development is the systematic process of designing and preparing all the courses offered in a particular subject. It is one of pedagogical exercises that are necessary for development of education. Its development requires a broader view that considers the needs and the impacts of students, teachers, institutions, employers and governments and includes the factors like content, teaching and evaluation strategies, teaching resources and facilities. Curricula may be organised at two levels. The first approach (Heywood, 2005) may be at a macro level, in which the decisions are made about the type of courses to be offered, the amount of time to be devoted to each, the way they will be arranged over the program and so forth. Second, the particular content elements and learning activities can be selected and organized to optimize the knowledge gained by the student. This later approach usually deals with materials within the courses and can be based on principles of teaching and learning and of curriculum design. The two types of organization may be compared to the adjustment as in tuning a mechanism or an instrument; first gross adjustments are made, and then fine tuning is carried out based on group requirements.

The design of the entire curriculum process is intended to illustrate the syllabus as being the outcome of a complex design activity. This involves the declaration of objectives and simultaneous design of assessment and instruction procedures that will cause those objectives to be obtained for a particular programme and institute.

As a discipline of engineering, Mechanical Engineering is not very old. Its relevance became more important with Industrial Revolution and ultimately manufacturing & power production led to its growth (Burstall, 1965).

3. GROWTH OF JADAVPUR UNIVERSITY: CASE STUDY FOR A DEVELOPING COUNTRY

In India, the desire for creation of centres of technical training came from the British rulers and it arose out of the necessity for the training of overseers for construction and maintenance of public buildings, roads, canals, and ports, and also for the training of artisans and craftsmen for the use of instruments, and apparatus needed for the army, the navy, and the survey department, in particular.

In India the colonial model of technical education with the establishment of Guindy College, Chennai (1794), Thomason College, Roorkee (1847), Poona Engineering College (1856), Civil Engineering College, Calcutta (1856) and Victoria Jubilee Technical Institution, Bombay (1887) went in one direction. The curriculum and the training in these colleges were geared mostly to meet the requirements of only subordinate grades of engineering services of the then British colony, India. However, a national model different from colonial model was attempted to be developed in Calcutta with the establishment of National Council of Education, Bengal and the Bengal National College & School in 1906.

Its main aim was to provide education - literary, scientific and technical 'on national lines and under national control' (Sarkar, 1946). The institution had four departments – Literary, Scientific, Technical and Commercial. The teaching section of the Technical Department imparted both theoretical and practical courses. The students had to attend laboratory work and workshop training along with classroom lectures. Thus practical handling, shaping, breaking, analyzing & measuring of materials was an important part of the training imparted in the Technical Department of the National College. Right from the beginning, the Bengal National College displayed this “three dimensional” system of education combining teaching with factory work. Other subjects taught included: Drawing – freehand & mechanical, Physics, Chemistry and Mathematics. The technical department had also a manufacturing section which did some industrial works for other business firms (Mukherjee, 1909).

For the promotion of technical education alone, in the same year, a second organisation, rival to the National Council of Education, named Society for Promotion of Technical Education (S.P.T.E.) was established and this later founded the Bengal Technical Institute (BTI), the first nationalist technical school in India. In BTI, two courses were offered: primary courses which include practical training in Mechanical fitting, electrical fitting, carpentry, drawing and surveying. And the secondary courses included Mechanical Engineering, Electrical Engineering, Dyeing & Bleaching, Industrial Chemistry and Economic Geology & Mineralogy. BTI also had a manufacturing department (Sarkar, 1946). On 25th May, 1910, the Society for Promotion of Technical Education and the National Council merged and formed the Central National Institution. Later it was renamed as the College of Engineering and Technology (CET) in 1929.

Time progressed and on 24th December, 1955, Jadavpur University was formally established with Dr. Triguna Sen as the Rector (equivalent to Vice Chancellor). As a reincarnation of the CET, Jadavpur University continued to abide by the noble ideals and aspirations of the National Council of Education, Bengal and created 3 separate faculties of broad disciplines in international line – Arts, Science and Engineering. Throughout its first decade the University continued to add new departments and new subjects in the curriculum with due regard to the industrial requirements of a growing nation.

3.1. History of institutional changes in curriculum at Jadavpur University: analysis

The present study shows that the curriculum for Mechanical Engineering courses at Jadavpur University has undergone a continuous change over a period of 50 years, because of the perceived notion of changes in curriculum framework imposed by the faculty as well as the regulatory body All India Council for Technical Education (AICTE) in the later years. As per standard procedure, the curriculum framework has been divided into some areas namely Basic Sciences, Humanities, Social Sciences and Management, Engineering Sciences, Professional Core Subjects, Electives, Technical Arts/Drawings, Workshops and Laboratories. Data on total periods allotted have been taken for the years 1966, '74, '86, '99 and 2009 and a percentage has been calculated (Table 1).

	Year 1966 (%)	Year 1974 (%)	Year 1986 (%)	Year 1999 (%)	Year 2009 (%)
Basic Sciences	17.65	15.93	8.5	9.58	8.82
Humanities, Social Sc, Management	7.45	6.97	5.67	5.34	5.88
Engineering Sciences	18.72	13.69	24.19	22.69	25
Professional Core Subjects	10.16	15.43	17	19.35	21.32
Electives	2.14	1.99	2.83	4	4.41
Technical Arts/ Drawings	18.98	17.67	15.59	14.68	11.03
Workshops	12.03	11.63	11.37	11.01	9.19
Laboratories	12.83	16.68	14.88	13.34	14.34

Table 1: Percentage Values of the curriculum framework based on the periods allotted over the last 50 years for the Mechanical Engineering Department

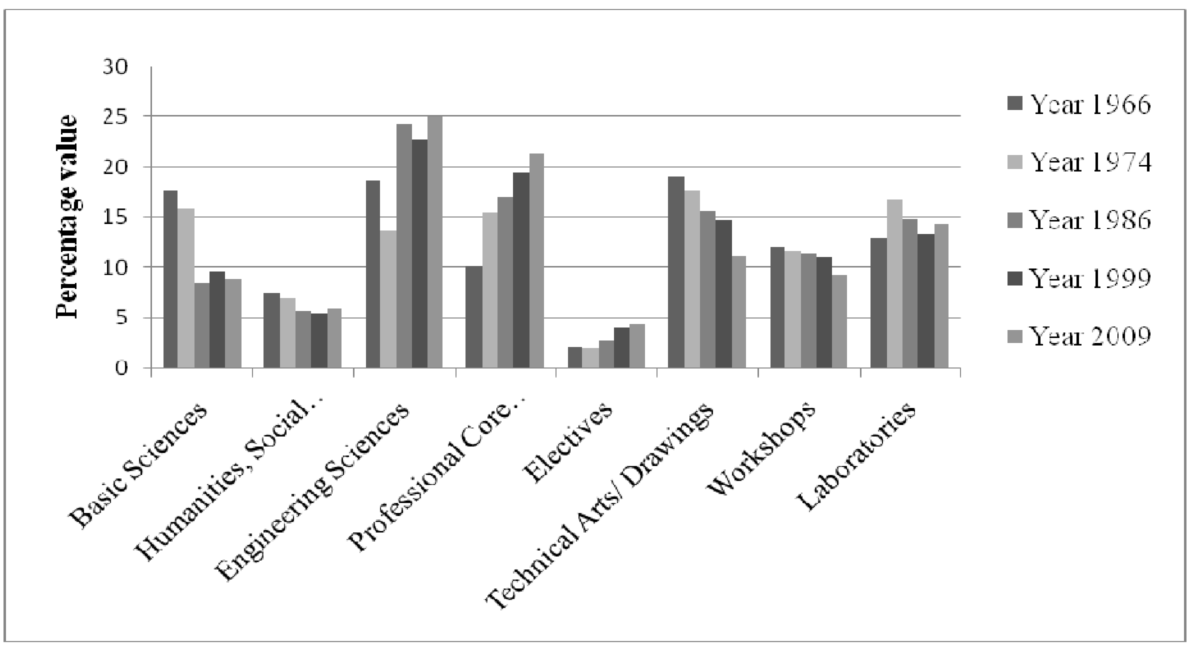

Figure 1: Variation in the areas from the year 1966-2009 in the Mechanical Engineering curriculum at Jadavpur University

A comparative analysis of the changing trends in the Mechanical Engineering curriculum has been shown in Figure 1 (Based on percentage values of periods allotted in Table 1). The analysis based on the cumulative calculations leads us to following conclusions regarding distribution of curriculum framework.

3.1.1 Distributions of Basic sciences

Basic sciences are responsible for generating fundamental thinking ability in students. An analysis of the percentage of basic sciences over the years shows a steep decline from the year 1986 onwards. This remarkable drop of about 8.83 % is indicative of the fact that during the early 1970s the courses were based on a five year duration which led to the introduction of calculus based science subjects like physics, chemistry as well as mathematics to a much deeper extent than what they are in a present four year curriculum. The integration of school and degree level engineering curricula needs a thorough study.

3.1.2 Distributions of Engineering Science

The percentage of Engineering Science has not undergone drastic changes (Table 1). This shows the trend has been towards increasing the percentage of engineering sciences in curriculum framework in order to instil in student's mind a sound pedagogic system which aims at providing the students with a clear concepts of engineering at the beginning of the learning stage itself and strengthen their foundation to enhance their capability of understanding when they deal with professional core subjects and electives.

3.1.3 Distributions of Social skills

The percentage of Social skills (humanities, social sc. & management) had decreased by 2.11 % till the late 1990s from 7.455 in 1966 to 5.67 in 1986, but tends to show a gradual increase in the recent years from 5.34% in 1999 to 5.88 % in 2009 (Table 1). World over, all the accrediting agencies are talking about the need of engineers having more communication skills, knowledge of economics, ideas of professional ethics etc. So, all the latest guidelines including ABET, Bologna or India's AICTE suggest percentage increase in social skill courses. To incorporate this, some sacrifice may have to be made at other areas and that is yet to be agreed upon unanimously. However, if we look at Jadavpur, it seems that the contribution to society by engineers can be increased with more emphasis on social skill in curriculum framework.

3.1.4 Distributions of Professional Core subjects

The numbers of periods allotted to Professional Core subjects have witnessed a steady increase over the past 60 years as depicted by the bar charts (Figure 1). The percentage of periods allotted to this field was 10.16 % in the curriculum framed for the year 1966, and has increased steadily to 21.32 % in the year 2009 (Table 1). This significant increase has been necessitated due to developments in the field of Mechanical Engineering into newer areas of energy, manufacturing and interdisciplinary areas as robotics, biomechanics etc. Also, as is traditional in Jadavpur University more stress has been put on fluid machinery, manufacturing technology and advanced computational techniques such as Finite Element Methods. These changes match the industrial needs as placements of alumni has shown. But this increase has been done at the cost of technical arts/ engineering drawing, workshop classes. Traditionally these were strong points of Jadavpur University (AICTE India, 2007).

3.1.5 Distributions of Electives

The percentage of Elective period allocation has seen a steady rise from 2.14 % in 1966 by 2.27 % to 4.41 % in 2009 (Table 1). This can be related to the point raised in the earlier conclusion that the students need to have core knowledge of the discipline. The specialized areas can be covered by electives (optional) which can be chosen by the student depending on his/her aptitude, as well as the requirement at that point of time of the industry. It must be clearly noted here that the need of industry varies with time. For outsourcing of some of the countries of software management, there was a requirement of engineering graduates. But with the development of climate change issues and the thrust on biomedical solutions, the number of electives have been increased as some of the following names suggest—solar energy, aerodynamics, computer aided design and manufacturing, biomechanics and biomaterials, advanced dynamics and vibration, design of thermal systems etc.

3.1.6 Distributions of Technical Arts/Drawings

The contribution of Technical Arts/Drawings to the curriculum framework was 18.98 % as obtained from the 1966 period allotment. But this has seen a remarkable drop since then and has decreased to just 11.03 % in 2009 resulting in a decrease of 7.95 % (Table 1). This shows less emphasis on hands on drawings over the period of time. The reason might be the perceived notion of lesser employment of students in consultancy organizations and advent of computerised drawing. The effect is yet to be observed because many of the engineering subjects particularly engineering mechanics needs a very good conceptual understanding of the physical system which needs good concept of technical arts/drawings.

3.1.7 Distributions of Workshops

The percentage of Workshops held during 1966 has dropped down steadily from 12.03 % to 9.19 % in the year 2009, a decrease of 2.84 % (Table 1 and Figure 1). This strengthens the report which says 75% of engineers in India are unemployable and they have cited the reason as more thrust on academics and theory (The Sunday Statesman, 2009). Engineering (or for that matter Technology) relates to practical applications. So there is a contradiction here that needs to be resolved even keeping in mind that the growth of the Mechanical Engineering discipline has been explosive.

4. CONCLUSIONS

The imposition of General Agreement on Trade in Services (GATS) regime in education sector necessitates enrichment and broadening of engineering curricula so that engineers will be better prepared to work in a changing global economy from now. The curriculum design has become a central paradigm in engineering education. Accords & treaties like Washington & Bologna etc. have been agreed upon to homogenize curriculum. Accordingly, AICTE, which is implementing this in India have formulated a curricular framework which includes 10-15% Basic Sciences, 15-17.5% Engineering Sciences, 10-15% Humanities social sciences and Management, Professional core 22.5-27.5%, Electives 19.5-25%, Seminar and industrial training 2.5-5% and Project 5-12.5%. However, author is of the opinion that even with cross-border movement of engineers, the national requirements should get priority in framing curriculum and syllabi of that country.

Novel curriculum design and introduction of innovative courses go a long-way in moulding the career of younger students into various walks of life in the society. In this respect, Jadavpur University has made great strides in designing their curricula. Considerable freedom and flexibility for the faculty to design relevant and innovative courses have earned a good reputation for the University. The institution has travelled a long way from a College of Engineering & Technology to Jadavpur University and successfully established itself as one of the better Indian research and teaching institution with a vast repertoire of courses offered.

Development of Indian technical education has been mainly on two models: colonial and nationalist. This particular institute taken for case study developed on a nationalist line (Sangwan, 1990). For a country, which is still categorised 'developing', emphasis has been more on hands on training, design & drawing and to some extent motivation of entrepreneurial skill (Khanduja et al., 2009). Small & medium industries development has been a thrust area of most Indian institutes' curriculum excepting Indian Institute of Technology (IITs) (Arakeri, 2006). That is reflected in the analysis.

Industrial feedback is a must for any curriculum framework that is absent in most of the educational institutions in India as well as in Jadavpur University. This has to be rectified. It can be reported here that in the Technical Education Quality Improvement Programme of the World Bank at Jadavpur University was allocated the task of spending a portion of the grant for services to community and economy which has been suggested to be included in curriculum framework at later stages (Saha, 2007). This is very important for developing countries which need to be addressed in similar studies.

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INTEGRATING BUILT ENVIRONMENT STUDIES THROUGH SUSTAINABLE DEVELOPMENT EDUCATION

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Abstract: The study sets out to crystallise the learning obtained from a pursuit to deliver ‘education for sustainable development’, in a higher education context and across eleven built environment professions, including the key engineering disciplines of civil, energy and environmental engineering.

This paper captures the key lessons, from a concerted ten-year drive to integrate sustainability thinking into the built environment disciplines at the University of Ulster, whilst building on international concepts. Funded initially by the Royal Academy of Engineers, this inter-disciplinary work required appointment of visiting professors, engagement with professional bodies, staff motivation and training, module design and development of appropriate pedagogy and assessment methods.

A continuum, involving evolution from Year 1 undergraduate sustainability awareness, through Year 2 sustainability application in technical modules, leading to final year sustainability integration across in-depth studies, design activity and research-focused dissertations, gave a structure and coherence to the work, with the need for a focused and broad-disciple staff team to maximise on the opportunity of success.

This integrative approach to ‘sustainability education being both complex and complicated’ was applied at Masters level. The challenge of sustainability thinking, in the context of international drivers, was embraced by students at all levels, with indications from students, module and professional surveys highlighting the benefits of multi-disciplinary projects and encouragement of complimentary ownership by all professions.

A focused staff sustainability group sought and obtained input and feedback from a Sustainability Visiting Panel, gave access to relevant case studies, allowed students and staff to engage in holistic challenges, while positive reports from external Accrediting Bodies added weight and content to a mature sustainability education.

Keywords: Sustainable Development, Pedagogy, Assessment, Module design; Embedding Sustainability

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1. INTRODUCTION

1.1 Education for Sustainable Development

This paper is set in the context of the UN International Decade of Education for Sustainable Development (DESD) 2005-2014. It is apparent that the various official DESD documents are consistent in outlining their vision for a world 'where everyone has the opportunity to benefit from education and learn the values, behaviour and lifestyles required for a sustainable future and for positive societal transformation' (UNESCO 2005). A mid-term review indicated: 'Anecdotal evidence suggests that the DESD has already started to make some difference in terms of influencing governments to establish DESD policies and strategies, engaging stakeholders and producing new tools and resources for ESD stakeholders. However, there is still a long way to go to achieve the ultimate goal of the DESD—a more sustainable global community.' (Mula and Tilbury 2009)

The United Nations University's Regional Centres of Expertise on Education for Sustainable Development (RCE) initiative recognised that RCE's are an evolving concept and drew attention to the RCE process as a promising example of 'social learning' and 'communities of practice', as well as a 'knowledge management system'. (Mochizuki 2008)

1.2 Non Statutory Professional Bodies

The UK engineering professions have sought to play a key role in the linking of sustainability to education in the context of their professional recognition of members and of under-pinning education programmes. The UK Engineering Council, as the professional qualification awarding body has guidance on the role of engineers in relation to sustainability. Six principles have been developed, to guide and motivate engineers, to achieve sustainable development (SD) in their work, and to meet professional obligations in achieving sustainability. These address the issues of building a sustainable society; professional and responsible judgments; exceeding legislative norms; resource management; adopting multiple views to solve problems; and managing risk. (Engineering Council 2009).

In support, the Royal Academy of Engineers, as a multi-discipline body introduced a 'Visiting Professor in Engineering Design for Sustainable Development' Scheme (1999 – 2008), and produced a set of Guiding Principles (Dodds & Venables, 2005), identifying the three mutually inclusive supporting elements of sustainable design as Eco-Centric, Techno-centric and Socio-Centric concerns.

As a key professional body, the Institution of Civil Engineers (ICE) has nine attributes for those who aspire to be professional members and chartered engineers; two sustainability-related attributes are shown in Fig. 1 (ICE3001A; 2009)

Group	Attribute
Engineering Application	A Ability to identify, review and select techniques, procedures and methods to undertake engineering tasks. B Ability to contribute to design & development of engineering solutions. C Ability to implement design solutions and contribute to their evaluation.
Sustainable Development	A Sound knowledge of sustainable development best practice. B Ability to manage engineering activities that contribute to sustainable development

Fig. 1. ICE 3001A (2009) Routes to Membership extract

1.3 University of Ulster Developments
The School of the Built Environment (SoBE) at the University of Ulster (UU), with 11 disciples, has been attempting to deliver environmentally related material and programmes in the 1990's, as a result of UK government directions (Toyne Report 1993). An interim review (Khan 1996) indicated that progress was slow across the UK; simultaneously UU developed an undergraduate programme in Environmental Engineering and consolidated environmental material in environmental health and civil engineering degrees. In 1999, SoBE, along with other UK Universities, obtained funding from the Royal Academy of Engineering to 'deliver SD across the built environment disciplines in the School' within its Visiting Professor scheme. The work was led by WA Strong (Project Leader); Dr Lesley Hemphill was appointed Project Officer in 2002 and two Visiting Professors assisted the work - Dr Jim McQuaid (1999 – 2002); Dr Brian Hanna (2003-2006)

2. SCHOOL OF THE BUILT ENVIRONMENT AT UNIVERSITY OF ULSTER

The traditional professions of civil engineering, architecture, construction and quantity surveying are central to the delivery of built environment design and construction phases, and have been well served by a comprehensive supply of educational programmes at undergraduate and post-graduate levels. Further development of built environment disciplines reflected the need for skills in other important themes and representing the breadth of the built environment processes across strategic and land planning, holistic and detailed design, procurement and construction, and facilities operation and maintenance.

	Energy Institute	ICE	CIEH	CIAT	
CIBSE	Energy & Building Services Engineering	Civil Engineering	Environmental Health	Architecture	RIBA
CILT	Transport Studies	**SUSTAINABLE DEVELOPMENT**		Housing Studies	CIH
CIOB	Construction	Building & Quantity Surveying	Property & Investment Development	Planning & Property Development	RTPI
	CIOB	RICS			

Fig. 2. Built Environment Disciplines and Professional Bodies in SoBE

Figure 2 shows the wide-ranging built environment under and post-graduate education provision, allowing opportunity for creative and inter-disciplinary learning and teaching as well as unified research and development (UU 2009).

The vocational and professional nature of built environment professions necessitates regulation for both academic standards and in providing under-pinning education towards professional status such as chartered engineer, builder, surveyor, architect, planner, environmentalist or environmental health officer. These professional bodies play traditional roles, primarily as member organisations, in accrediting educational programmes and representing the body in advocacy and learned society functions, and also having 'royal charter' responsibility functions for statutory roles such as health and safety and for ethics - leadership and responsibility for SD falls within this latter category. Typically of others, the ICE, one of the oldest professions, has developed significant corporate SD strategies (ICE

2007). This new professional response to the sustainability agenda is reflected mainly in the objectives and education accreditation requirements of these built environment professional bodies, with some seeking more deeply embedded sustainability in degree programmes.

Graduates from the built environment courses have opportunity to develop fulfilling careers, to gain long-term employment and be agents for change in SD and ethics, at both home and abroad and in public and private sectors. These employability and influencer roles have been cited as key marketing tools to attract undergraduates, whilst the deeper role of professional leaders has been studied, confirmed and recorded by the Royal Academy of Engineering (Royal Academy 2006).

3. SUSTAINABLE DEVELOPMENT EDUCATION IN SoBE

3.1 Sustainable Development Group

The Sustainable Development Group (SDG) was formed in 1999 to deliver the Royal Academy of Engineering SD programme, observing at that stage that there were no other significant multi-discipline SD examples in UK Higher Education. It commenced its quest for SD integration from a low base, by carrying out a module audit to determine the explicit and implicit references to SD in all built environment module objectives. Whilst the new Environmental Engineering course rated satisfactory with 45% of modules including SD, this was contrasted by traditional Quantity Surveying and Civil Engineering courses, accredited by RICS and ICE respectively, scoring under 5%. This raw data presented a weak position which necessitated a Position Paper on SD integration, in which a new ROAMEF framework was applied:

Rationale – the purpose(s) that the teaching or case study is intended to fulfill;
Objectives – the project objectives that will ensure delivery of the pedagogy material;
Appraisal – the justification that the project will meet the Rationale purpose(s);
Monitoring – the arrangements for ensuring that the project proceeds to the plan;
Evaluation – the arrangements for post-examination of the utility in meeting its purpose(s);
Feedback - the application to subsequent projects of lessons learned in the execution

Little evidence existed in how to develop this sustainability in a large multi-disciplinary higher education school, so the SDG sought accountability and relevance in appointment a Sustainability Visiting Panel (SVP), drawn from external experts representing the economic, environmental ands social pillars of SD, and it met annually SVP to give advice and support.

The SDG, with its Visiting Professors, appraised the options for breadth and depth of SD teaching and learning, while communicating and feeding back to the Royal Academy Network. The broad approach applied to competencies in decision making, risk taking, design selection, materials choices and more across several themes issues in pursuit of balance of the competing demands of environmental, social, economic and resource management zones. A continuum for sustainability education was designed to provide a foundation of SD *Awareness* [Phase I], to support more detailed studies in lectures, and informed by *Case Studies* [Phase II], and to facilitate and underpin a range of SD *Integrative Projects* [Phase III], design teamwork and individual studies (Fig. 3). This continuum also facilitated an appreciation of how SD can influence the built environment phases of concept, design, construction and maintenance, and across typical themes such as planning, biodiversity, design, facilities management, construction, environment, social impact, waste management, water resources, transport systems and urban development.

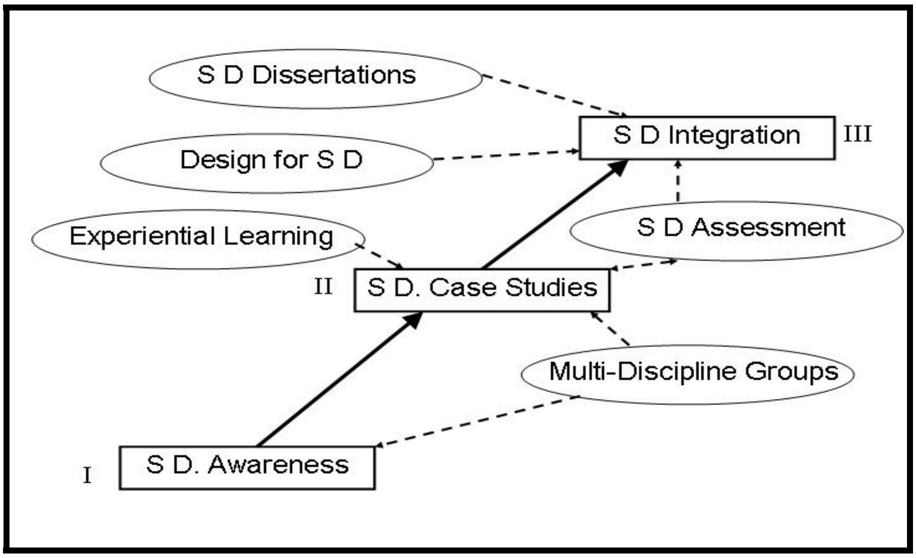

Fig. 3 UU Continuum for Sustainability in Curricula

3.2 Year 1 (Level 4) – Sustainability Awareness

The drivers for this new Year 1 'Communicating Sustainability' module for a range of built environment disciplines were: a. vocational courses meeting professional body requirements; b. simultaneous multi-discipline delivery to professional groups; c. sustainability awareness experience underpinning future studies; d. response to international & national trends in sustainability; e. challenging student social conscience; f. mobilising of motivated staff, and g. delivering rigorous assessment of sustainability information

The 10 credit point module was initially developed as a 'forced marriage' between teaching in Information Technology (IT) and SD [Model A], evolving to a partnership with SD material leading [Model B]; IT material was reduced, as students already had basic IT skills, and allowed the structuring of a 20 credit point module in which SD was integrated with new teaching on Geographical Information Systems (GIS) [Model C]. See Fig. 4.

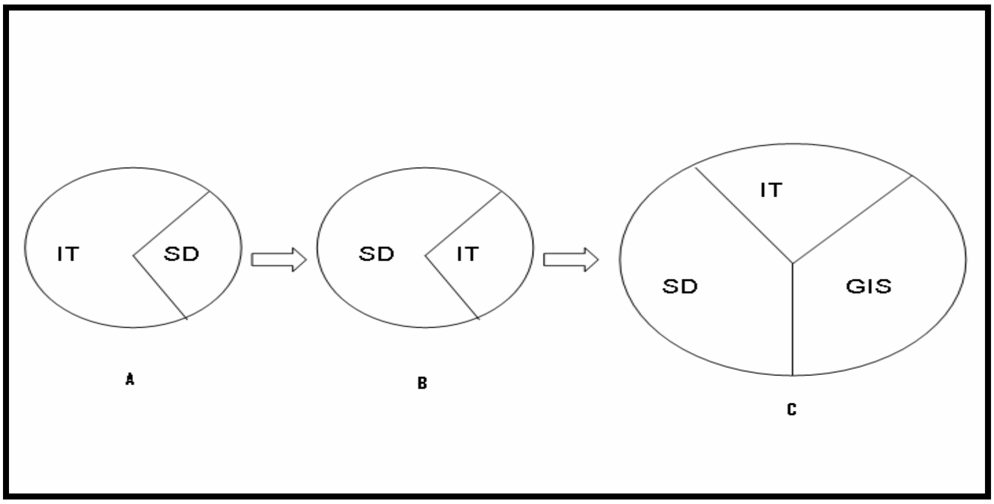

Fig. 4 Evolution of sustainability awareness module structure

This Model B module covered basic knowledge of proprietary software applications and oral and written skills, while addressing the SD themes of water, transport, energy, construction, planning, regeneration, sustainable communities and social issues. Inter-active lectures by motivated staff and visitors on SD themes, with emphases on Student-Centered Learning, were supported by seminars and practical workshop sessions in the computer laboratory. The UU interactive learning environment ensured that material was accessible from a WebCT portal, and this was reinforced by substantial reading material via the UU Learning Resource Virtual Built Environment Library (VIBEL 2007). Module assessment included a purpose-built online SD test, using multiple choice, true/false and 'matching statements' questions, selected, against themes randomly from a bank of 120 questions.

3.3 Year 2 (Level 5) Activity

Each degree programme was encouraged to ensure that SD was embedded into its curriculum, with the SD thread strongly identified across teaching and learning. It was evident that this drive was dependent the motivation and ability of staff members, some of whom had been traditional lecturers in delivering fundamental science and engineering, while other staff had the opportunity to integrate SD into vocationally oriented topics. The SDG provided three types of support: a. development of 2 major Case Studies on i. Regeneration of Mossley Mill development (with Newtownabbey Borough Council); ii. Sustainability in the development of a Community Treatment Care Centre (with N Ireland Health Estates); lectures, documents and display material were made available; b. development of mini SD Case studies, to be used in class as a means of integrating SD into current taught material; c. Advice and support for staff in developing SD content and studies for existing modules.

3.4 Year 4 (Level 6) Activity

In this phase, the major SD thrust was:

a. Applied module delivery in which SD assignments provided a vehicle for integrated studies – Civil Engineering, Environmental Health and Planning & Property Development were highly active in this approach, while the suite of Renewable Energy studies across several disciplines gave significant input to the 'Energy and Climate Change' debate;

b. Design modules where SD monitoring and appraisal greatly assisted in decision making and whole life analyses – Building Services and Civil engineering degrees fully engaged;

c. Dissertation studies in which SD thinking gave greater understanding; the SD requirement gained considerable momentum, with up to 30% of all final year Dissertations (over 200) having a significant SD element in the study objectives.

3.5 Masters (Level 7) Activity

The development of an SD Module at level 7 has been taken by Masters programmes in Infrastructure Engineering, Environmental Health and Construction Project Management as well as sharing material with Masters students from Architecture. The opportunity for in-depth inter-disciplinary studies has been beneficial in team-building and appreciation of the application and solution of SD issues, leading to new understanding and analyses in consensus building, behavioural change, integrated transportation, energy conservation, climate change mitigation and adaptation, SD appraisals and measurement. It is proposed that students from the new Masters in Transport Planning and enhanced Master of Engineering will join this multi-disciplinary cohort.

3.6 Associated Activities

The SDG has built up or encouraged a series of associated activities, to support and complement the teaching pedagogy across the four levels of study:

a. Series of Emotive events in which several disciplines debate and develop outputs in poster format; i. Emotive Evening for final year under-graduates in Property, Engineering, Architecture to debate 'Making Poverty History'; ii. Emotive Morning for seven undergraduate Year 1 disciplines to consider 'SD aspects of UU Campus in 20 years'; iii. Emotive Afternoon for all Masters students in Faculty of Art, Design and the Built Environment to develop resolutions for issues such as 'Food Security';

b. SD Research in cross-cutting themes from built environment disciplines – current SDG studies include Sustainable Water Evaluation Programme; Water Impact on Highway Performance; Sustainable Urban Community Modelling & trade offs; Sustainable Rural Communities; Sustainable Public Health Engineering; Smart Growth models.
c. SD Research with other disciples; project proposals include Retrofitting of Social Housing; Environmental aspects of Distance Learning programmes; Sustainable Highway Performance;
d. Development of a Residential in Environmental Health to seek integration of SD;
e. Support and advice to external clients on sustainability profiling and measurement; projects include Maze Long Kesh as potential National Stadium, disused Landfill Site as Giants Park;
f. Membership of several SD stakeholder bodies and Ministerial Advisory Bodies (Architecture, Construction, Waste Management);
g. Authors of Sustainable Development Policy Directory (Strong, Hemphill 2006);
g. Development of academic enterprise suggestions and projects – proposed development of a SD Game, SD professionals' symbiosis event; SD chief executive lunch;
h. Interaction with and contribution to Higher Education Academy programmes vis-à-vis Geography Earth & Environmental Sciences (GEES), Centre for Education in the Built Environment (CEBE), Council for Higher Education in Art & Design (CHEAD), Centre for Sustainable Communities Achieved through Integrated Professional Education (C-SCAIPE), Engineering Subject Centre at Loughborough;
i. Monitoring of all aspects of the SD provision through i. Documented Student Feedback (SF) on SD awareness and the SD Online testing; ii. Contribution to the Royal Academy of Engineering (RAEng) SD Visiting Professor Annual Workshops; iii. UU Sustainability Visiting Panel (SVP) Annual Meeting; iv. Module evaluation; v. Research annual reviews.

4. CONCLUSIONS

This paper presented a structured approach to the challenge of communicating and developing sustainability in a higher education environment. It addressed the compelling drivers in international and national jurisdictions as set at both generic governmental level and in the context of education, highlighted by the UN Decade of Education for Sustainable Development 2005 – 2014, giving a vital backdrop to this contribution to the transformation and embedding of sustainability education. It concurred with the UN RCE's approach to SD pedagogy of 'social learning', 'communities of practice', and 'knowledge management system' (Mochizuki 2008). Within the wide range of activities associated with the provision of the built environment, professional bodies play key roles in protecting the well-being of members and society, across issues including ethics and education, whilst bringing sharper focus to and appreciation of the sustainability agenda. They enthusiastically approach SD at strategic and operational levels, within their governance and at higher education programme accreditation phases. This has assisted in the imperative to introduce SD at all stages in undergraduate and masters degree courses, in order to establish and build on a foundation for further studies and to ensure that SD is seen as an holistic and integrative study, across the lifetime of graduates.

The UU vision for and journey towards the evolution and development of sustainability education has been conceptualised in a continuum, with 'communicating sustainability' as the base. The following key conclusions have been derived from a ten year period of SD integration into the higher education delivery at UU SoBE:

- SD awareness has a prolific international context, cutting across government and society
- Stimulating foundation lectures are important to gain early multi-discipline engagement
- Access to comprehensive range of quality support material gives key opportunities
- Use of e-learning and online SD testing is a learning and motivation experience

- SD material sits readily alongside all built environment disciplines
- Student teamwork is enhanced through SD inter-discipline teaching groups
- Balance between academic staff engagement and external expertise ensures SD currency
- SD case studies inform and challenge inter-disciplinary teamwork
- Multi-disciplinary activity at Masters level has a richness and interrogative factors
- The Emotive events bring excitement and challenge to all delegates
- Student behavioural change can be an indirect outcome
- Professional bodies support and learn from this integrated and holistic SD strategy
- Links between Teaching, Research and Academic Enterprise are essential

.It is anticipated that the journey towards fulfilling and transformed sustainability education can be translated across other less technical higher education themes and discipline groups as the SD concepts, methodology and application have resonance with human, social, natural, manufactured and financial capitals.

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SUSTAINABILITY PRINCIPLES PROVIDE A FRAMEWORK TO FACILITATE INTEGRATION OF DESIGN PROCESSES.

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Abstract: Engineers and built environment professionals have been criticized for giving insignificant time to the design phase of projects; architects are considered as designers, leaving the roles of working out details and costs to engineers and surveyors. The advent of 'Achieving Excellence in Construction' has led to more integrated approaches, holistic project delivery through procurement, appointment of joint venture multi-discipline consortia and long-term approaches by considering projects across conceptual, design, construction, operation and maintenance phases.

This paper appraises the need for and delivery of an integrated approach by engineers to design, set in the context of sustainability, avoiding a 'contract designer' profile and thereby leading to an holistic design process and more sustainable product. Increased understanding of sustainability has allowed higher education students to identify with the connections across several themes such as energy, construction, waste, water, biodiversity and transport, so that a linear approach to design is replaced by integration and feedback evaluative mechanisms.

This sustainability-led design thinking, prompted by UN, UK and RoI drivers, as well as degree accrediting bodies, has been developed with undergraduates at the University of Ulster. The critical encouragement of students to adopt lateral thinking problem solving, learn from successes and failures, apply sustainability measuring systems in design decision-making, consider environmental, social and economic implications simultaneously and re-direct project solutions away form technical answers to the rationale for the project, has inevitably involving radical alternatives.

The paper content is drawn from considerable design teaching experience across engineering disciplines, with input from industrialists, student reviews and external professional body accreditation panels. It demonstrates the benefits of holistic design processes, systems thinking, and adopting a long-term approach to design to ensure that it is an integrative activity.

Keywords: Sustainability; Design; Holistic solutions; Multi-disciplinary projects

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1. INTRODUCTION

1.1 Sustainable Development Context

Strategies, governments, professional bodies, local authorities, environmentalists, non-governmental organisations and a myriad of disciplines have signed up to the concept of Sustainable Development (SD), to the point that the Bruntland definition: 'development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs' is widely used, if not fully understood. (WCED, 1987)

The UK Sustainable Development (SD) Strategy further highlights the aspiration 'to enjoy a better quality of life' (DEFRA 2005), adding to the complexity of this triple bottom line approach of a balance across Environmental, Economic and Societal elements with four priority areas for immediate action of: Sustainable Consumption and Production; Climate Change and Energy; Natural Resource Protection and Environmental Enhancement and Sustainable Communities; changing behaviour is a key cross cutting theme.

The Irish SD Strategy has similar goals 'to ensure that economy and society in Ireland can develop to their full potential within a well protected environment, without compromising its quality, and with responsibility towards present and future generations' (DoE RoI 1997).

1.2 Professional Body Context

Professional Bodies have sought to play a key role in the linking of Sustainability to Engineering. The UK Engineering Council's guidance describes the role of engineers in relation to sustainability. Six principles have been developed, to guide and motivate engineers from many disciplines to achieve sustainable development in their work, and help to meet professional obligations, addressing contribution to a sustainable society; professional and responsible judgements; exceeding legislative norms; resource management, and adopting multiple views to solve problems and managing risk. (Engineering Council 2009).

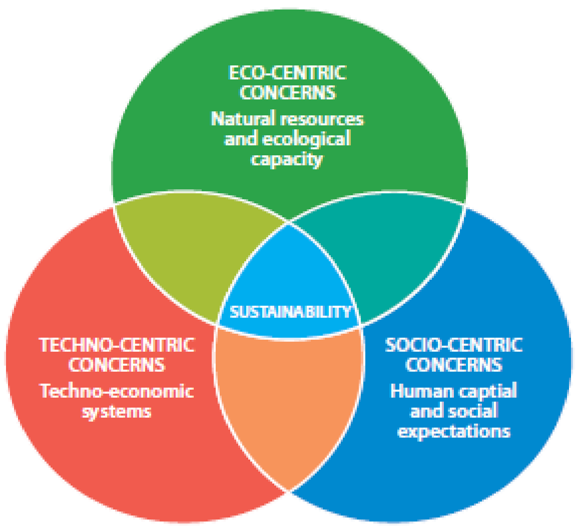

Fig 1. Engineering Design (Dodds & Venables 2005)

The Royal Academy of Engineers introduced a 'Visiting Professor in Engineering Design for Sustainable Development' Scheme (1999 – 2008), and produced a set of Guiding Principles, identifying the three supporting elements of sustainable design in Fig. 1.

The Institution of Civil Engineers has nine sets of attributes for those who aspire to be professional members and chartered engineers; two are shown in Fig. 2 (ICE3001A, 2009)

Group	Attribute
Engineering Application	A Ability to **identify, review and select** techniques, procedures and methods to undertake engineering tasks. B Ability to contribute to **design** & development of engineering solutions. C Ability to implement **design solutions** and contribute to their evaluation.

Sustainable Development	A Sound knowledge of **sustainable development** best practice. B Ability to manage engineering activities that **contribute to sustainable development**

Fig. 2. ICE 3001A (2009) Routes to Membership extract

1.3 Higher Education Context

Higher Education is being challenged to address SD through several drivers. The UN Decade of Education for Sustainable Development 2005-2014 goals (UNESCO 2003), set challenges for all levels of education. In support, the EDU-COM Conference (2008) recognised that people around the world are experiencing a fundamental transformation towards knowledge-based and knowledge-dependant communities, facilitated by improved information and communication technologies. Higher education for SD is seen as a process of learning how to make decisions that consider the long-term future of the economy, ecology and equity of all communities' Capacity development is a key task of higher education (Kaen, K 2008)

1.4 Built Environment Context

'60% of a nation's fixed capital formation is provided by the built environment industries and professionals' stated the UK Government Chief Construction Advisor (Morrell P 2010), and therefore contribute to 'quality of life'. This service operates across all phases of a project.

The Office of Government and Commerce is an independent office of HM Treasury, established to help government deliver best value from spending, and has set key goals for progress: value for money; projects on time, quality and cost; getting best from Government Estate; delivering sustainable procurement and sustainable operations; supporting government policy goals; improving capability in procurement, project and programme management (OGC 2010). These goals have significant relevance to the built environment.

1.5 Design Context

Global concepts are being translated into local applications in the form of Local Agenda 21, as part of the action plan agreed at the 1992 Rio Earth Summit (Agenda 21 1992). This is described as both a *process* – 'engaging and empowering the community to influence its own future' and a *product* – 'a better, more sustainable future'. This fresh approach to tackling Local Agenda 21 is replicated in the DETR By-Design Report (By-Design 2000), and at the heart of this report is the 'need for Engineers and others to 'work it out for yourself'. The holistic nature of Design is emphasised in the Planning Policy Guidance 1: "good design should be the aim of all those involved in the development process and should be encouraged everywhere". By-Design uses this approach, for an Urban Design problem, to identify key prompts such as character, continuity and enclosure, quality of the public realm, ease of movement, legibility, adaptability and diversity.

'Improving quality of life through design' is the strapline of the Commission for Architecture in the Built Environment' (CABE 2010), and its work in Design Reviews, publications and as a watchdog body for design across all elements of infrastructure, urban places, buildings and rural development bring immense benefits to society.

Problem solving and awareness of global issues is common to several disciplines. Typical of this universal desire for integration is the non-engineering writing, Futurewise, by economist, medic and Christian writer, Dr Patrick Dixon, in which six faces of global change are identified under the banner of 'either we take hold of the future or the future will take hold of us' (Dixon 1998).

1.6 Commentary

This brief review of literature and context-setting to consolidate relationships between SD and Design, indicate their inter-dependence in delivering the built environment, as well as relevance to all engineering disciplines. Higher education has a vital opportunity to contribute to these agenda and support engineers' development. The diverse sources point to the need for Engineers to take charge of the globe, to preserve the Natural Environment and to be fully equipped for now and the future, operating within relevant ethical standards, primarily in the interaction between the principles of Sustainability and the practice of Design.

2. SUSTAINABLE DEVELOPMENT & DESIGN – COMMON THEMES

2.1 Design Philosophy

The delivery of any built environment project should be seen in the continuum of Feasibility – Design – Construction – Operation – Maintenance – Demolition; hence the design phase is not an exclusive activity, but contributes to the overall sustainability of a project at several stages. Appraisal of SD themes indicates that it is imperative to have design solutions for built environment projects which address issues such as Energy, Transport, Water, Construction, Waste Management, Biodiversity, Project Economics, Social Impact, Environmental Impact, Community Engagement, Materials, and Procurement et al. These SD and design themes can be mapped onto and assessed using a number of SD assessment systems or tools.

At Higher education level, most vocational degrees in the built environment family are required to meet professional accreditation standards which expect SD integration and an ability to address design issues. These challenges have been approached in two distinct ways: a. An elemental *product approach*, in which elements are designed primarily with best practice in mind; this philistine scientist approach is solely driven by Codes, directed by software packages, evidenced by complex analyses and packaged into a portfolio of contract documents; b. A *process approach* in which systems thinking is applied at all stages to ensure that sustainability is at the heart of decisions, such that design decisions involve back-tracking and future proofing; this results on integration of systems and disciplines.

2.2 Design Pedagogy

This process approach to design, applied to the teaching of design at undergraduate level for civil engineering and building services engineering students at the University of Ulster for over 10 years, is conceptually shown in Fig 3. and described schematically in Fig 4. The schematic diagram indicated that over 70% of time is spent on the decision making element of the process with the remainder on the detailed 'product design' phase. Hence the decision making phase is central and this has been developed through a balance across both 'banking theory' and 'discovery based theory' of accumulating material.

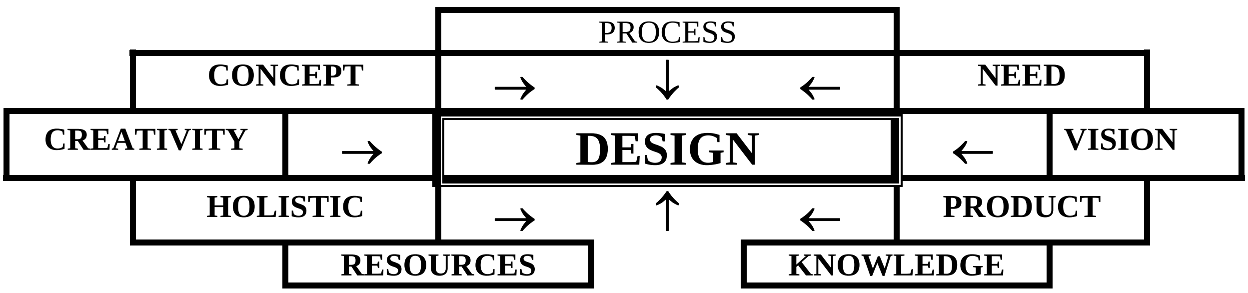

Fig 3. Conceptual Process Approach to Design at Undergraduate level in UU

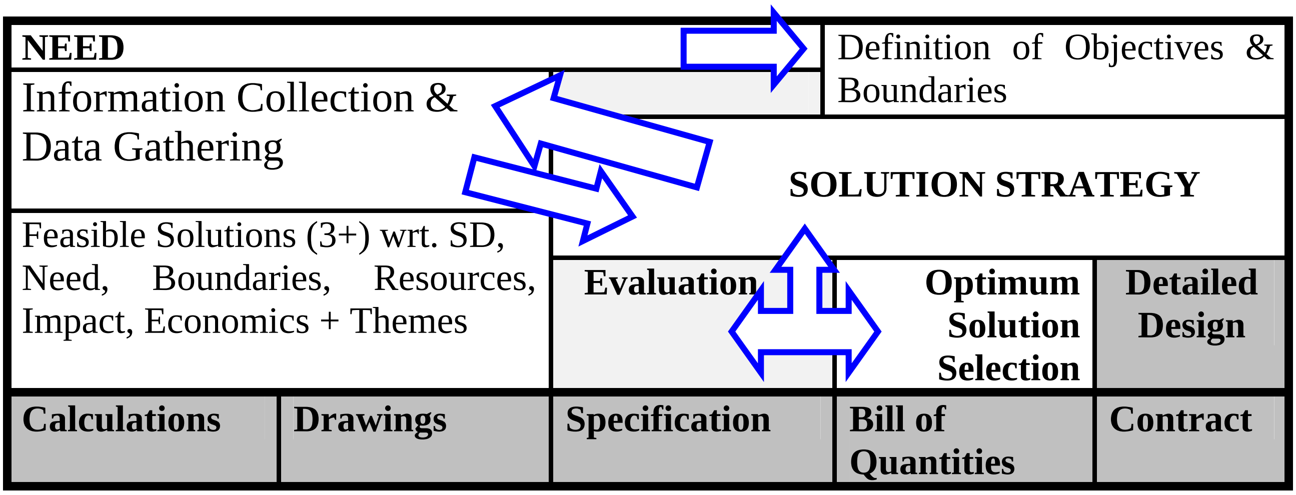

Fig 4. Process Design Approach

The *Banking Theory* of education assumes that information is acquired and banked or stored up for later recall and application. In context of banking theory, a careful analysis of the teacher-student relationship at any level, inside or outside of education, reveals its fundamentally *narrative* character. This relationship involves a narrating subject (the lecturer) and patient (the students). The contents, whether values or empirical dimensions of reality, tend to the process of being narrated to become lifeless and petrified. (Friere P 2010).

In contrast the *Discovery Based Theory* expects students to obtain and appraise information in order to be able to optimize its use and value. In psychology and education, learning is commonly defined as a process that brings together cognitive, emotional, and environmental influences and experiences for acquiring, enhancing, or making changes in one's knowledge, skills, values, and world views (Wikipedia 2010). This approach suits the integrative and multi-discipline requirements of sustainability design.

2.3 Design Programme

Undergraduate degrees, which aspire to provide graduates who have the attributes of a built environment professional body, will have elements of design and SD at all levels of the degree programme – typically: awareness in Year 1; elemental design and SD relevance in Year 2 and detailed multi-disciplinary design and SD concepts in Year 3.

This paper uses the design module and experience of the Year 3 (final year) Design activity in the School of the Built Environment at UU for engineering degrees which operate in the built environment disciplines – civil engineering and energy and building services engineering. Staff facilitates undergraduates to engage in engineering design against a background of SD awareness and single thematic applications (waste, water, transport, etc) so that they can 'address design challenges from a holistic approach'. Understanding, teaching, leading to facilitating, and directing of this Conceptual Design thrust has given responsibility and opportunity to embrace new approaches and influence graduate thinking and career pathways.

Fig 5 sets out a typical Design lecture, tutorial and workshop programme in 2-hour sessions, along with assessment points, while Fig 6 gives a range of engineering projects which have been used to allow students to develop their SD design capabilities. These projects are allocated randomly, but have served to give all students a similar design learning experience, and each project is supported by a similar industrially sourced case study.

a.

Teaching & Learning by 2 hour Sessions					
1-2	SD & Design Concepts	3	Learning Theories	4	Decision making systems
5-8	Case Studies from industry	9-12	Group brainstorming	13-16	Group Outputs
17-18	Group Assessment	19	Individual design	20	Design Review

b.

3	'Conceptual Design' task (20%) [Individual]	16	Group Poster (20%) [Team]
16	Individual Interviews by industrialists (15%) [Individual]	16	Group Report (25%) [Team]
20	Individual Design Task (20%) [Individual]		

Fig. 5a. Design Studio timetable; Fig. 5b. Assessment by percentage

Municipal Waste Treatment	Airfield Site Development	Waste Landfill Site	Railway Route Development	Marina Site & Layout Selection
Energy from Waste	Renewable Energy Development	Water Laboratory Selection	Marina Breakwater Design	Eco Village Development
Sewerage & Flooding Design	Energy from Water	Wind Farm Development	Wastewater Plant	Water Trunk Main Route
Upland Water Scheme	Rural Sewerage Development	Urban Traffic Congestion	Town Bypass Project	Aquarium Selection
Sports Museum Design	Transportation Design	Island Infrastructure	Racing Track Development	Off-Shore Wind Generation

Fig 6 Student Group Project range

2.4 Design Assignment and appraisal

Each assignment servers to develop the deeper SD & design relationship:

Assignment 1: Conceptual study requiring students to develop 'holistic philosophy' – typically 'learning from failures'; 'design - art or science?'; 'design behavioural change'; 'Developing World and Environmental issues' (Megacities 1995)

Assignment 2: Group Project Poster, allocated randomly, using topics from, Fig . 6 above; assessment by Industrial Panel (IP) of 4-6 senior engineers;

Assignment 3: Individual Interview on Poster content, by IP;

Assignment 4: Group Report (10k words) by IP:

Assignment 5: Individual Design task with unique brief, and costs.

It is evident, from scores, external examiners and SD Visiting Professors, that this design study is both attractive and solicits high student engagement. Appraisal of scores over 10 years, in Fig 7, show that performance has been high, typically 65% average compared to 62% for taught modules, and no failures.

		YEAR	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	Average
Assignment	Student Nos	.	33	28	27	19	36	19	17	15	20	18	21	23.0
Concept	Individual	20%	62.6	67.8	68.1	63.8	63.14	67.5	63.7	70.1	59.6	65.7	58.6	64.6
Poster	Team	20%	63.8	65	65.7	69.5	61.94	62.8	59.5	65.2	64.7	66.7	65.7	64.6
Interview	Team	15%	61.2	64.8	64.2	65.3	63.67	63.9	62.8	64	61.9	65.6	66	63.9
Report	Team	25%	68.4	65.8	64.2	66.8	66.17	65.5	64.1	65.4	66.7	64.7	69.3	66.1
Design	Individual	20%	71.8	63.3	69.6	71.1	66.75	65.2	65.3	65.2	68.1	59.7	62.4	66.2
Total		100%	65.9	65.4	66.4	67.5	64.46	65	63.2	66	64.4	64.4	64.6	65.2

Fig. 7 Design Module Performance Average scores over period: 2000 - 2010

Standard deviation evaluation for this period, in Fig 8, also fails to clarify the consistent performance. Observation, student surveys and anecdotal evidence indicate that students compete aggressively with each other and for honours classification marks, resulting in ‘mark bulking’, as accumulative assessment allows them to re-direct effort and deliver enhanced performance. Similarly, the marking of group work has led to close awareness of individual effort and ability.

		YEAR	2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000	Average
Assignment	Student Nos.		33	28	27	19	36	19	17	15	20	18	21	23.0
Concept	Individual	20%	12.83	6.16	3.82	5.81	6.63	4.03	4.28	3.1	8.56	1.57	7.12	5.81
Poster	Team	20%	5.31	5.11	4.7	3.17	3.93	5.03	3.78	3.03	6.39	3.69	8.55	4.79
Interview	Team	15%	5.97	4.1	4.5	3.37	4.6	4.42	3.97	5.79	3.63	3.78	4.34	4.41
Report	Team	25%	4.08	7.12	5.26	3.01	7.93	4.98	4.4	5.42	4.01	4.27	6.12	5.15
Design	Individual	20%	9.64	4.33	4.62	6.65	6.22	6.91	7.26	8.69	7.54	6.74	9.4	7.09
Total		100%	6.58	4.15	3.46	2.92	3.18	4.24	3.09	3.64	3.79	2.13	5.31	3.86

Fig. 8 Design Module Performance Standard Deviations over period: 2000 - 2010

2.5 Commentary on Design Elements

The following points demonstrate lessons learned from UU and issues to be addressed

i. *Staff* members are drawn from those who have had experience, both good and bad, in practices, and who are versed in the primary disciplines of Sustainable Engineering (municipal, environmental, civil, infrastructure, building services);
ii. *Industrialists* from 6-10 consulting engineering practices annually deliver live case studies, provide design briefs, act as mentors during group design, assist in assessment of posters and interviews and give formative feedback on Design process;
iii. *Continuing Professional Development* Certificates are awarded to industrialists;
iv. *Conceptual Design Assessment* requires students to appraise multi-discipline ‘what if’ issues and give commentary;
v. *Systems Thinking approach* involves an adoption of the Waterfall Diagram (Boehm 1976) which identifies a series of discrete events: User Requirements – System Requirements – Discipline Requirements – Detailed Design – Manufacture (alias Construction) – Integration (Assembly) – Acceptance;
vi. *Decision-Making* is central to the discovery based theory, and this uses the tool of Brainstorming, involving a small group of creative people in idea-generating sessions under controlled conditions. As groups of students approach any problem, the need to reach solutions which meet needs, live within reasonable boundaries, and are defensible give rise to the use of Decision-Making Matrices. Management theory describes this as ‘a system leading to the conscious selection of a course of action from among available alternatives to produce a desired result’ (Meggison 1992);
vii. *Tutoring from Staff* and industrialists embrace the processes and elements of sustainable development & measurement, pre-design planning, risk assessment, environmental impact, emergency planning, decision making, financial, contractual and procurement;
viii. *Case studies* from industry are allocated separately to each group on a random basis and have included liver projects as shown in Fig. 6.

3. SUSTAINABILITY DESIGN APPRAISAL ~ CONCLUSIONS

3.1 Student benefit for a range of communication and assessment techniques; such as sketching, optioneering, optimisation, technical, environmental, financial, teamwork, constructability, conceptual thinking. Student performance is enhanced by a balance of group and individual work. Final summative assessment tends to ‘bulk marks towards to the median score’, due to the accumulative effect of regular formative and diagnostic feedback, student competition for marks and the high level of engagement with the design experience. Not all students favour this conceptual approach, with some preferring taught material.

3.2 Industrial input should be monitored by: a. Academic observation of ‘consistency of approach in case study delivery’, and evaluation of student support; b. Feedback Questionnaires to seek commentary on design processes, student products and potential ‘continuous improvement of Design module’.

3.3 Design teaching must be supported by normal University appraisals

3.4 External Examiner engagement is vital for independent academic review.

3.5 Input and commentary from relevant accreditation bodies (ICE, CIBSE and Energy Institute) brings value and critical observation at all levels.

3.6 External recognition gives currency and credibility; august bodies such as The Royal Academy of Engineering can add value - UU student Group Posters have gained awards.

3.7 External evaluation from leading academics or practitioners is valuable - two UU Visiting Professors have critiqued the entire design processes and outputs

3.8 Continuous improvement can lead to enhanced experiences for all parties, through academic appraisal; an Integrated Deign module at post-graduate level has evolved.

3.9 All engineering disciplines can benefit from a systems thinking approach to SD integration.

3.10 The authors acknowledge the support and guidance given by Industrials and other academic staff, external bodies and experts in the delivery of this Design module,

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EMI FOR ENGINEERING EDUCATION IN ARAB WORLD AND TWENTY FIRST CENTURY CHALLENGES

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Abstract: Developments in engineering, as well as modern technologies are considered the most important requirements for the Twenty First century in the globalised world. Recent research has shown that there is a significant knowledge gap in the required level of international communication for engineering graduates in the Arab world. This is because the medium of study there is primarily Arabic. To overcome this problem, it has become an urgent necessity to implement English as a medium of study.

This paper presents an investigation, which was carried out from the available literature to find possible ways of implementing English Medium Instruction (EMI) in engineering education. This paper also focuses on some non-English speaking countries outside the Arab world, such as the Netherlands, Korea and Indonesia, which have already implemented EMI in engineering education. This study focuses on the problems faced by these non native-English speaking and non-Arabic countries and explores the possibilities of putting into practice the solutions suggested. The paper concludes that in order to improve the engineering education system in Arab countries, it is necessary to implement EMI. Pursuing the internationalisation of the system will achieve a world standard level, not only in engineering, but also in communication skills, for engineering graduates.

Keywords: EMI, engineering education, globalisation, Arab world, bilingual education.

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1. INTRODUCTION

The Arab World refers to the countries where Arabic is the official and first language. Geographically, it stretches from the Arabian Sea in the east to the Atlantic Ocean in the west, and from the Mediterranean Sea in the north to the Horn of Africa and the Indian Ocean in the southeast. The total land area is 11,188,892 square kilometres. The Arab world consists of 22 countries and territories with a combined population of 335 million people straddling North Africa and Western Asia, Al- Alkım (2008).

The 21st Century has introduced many challenges in engineering education. Information technologies hold out the promise of new scientific discoveries, higher standards in communication and increased production, leading to a higher quality of life. The most important challenges to engineering education in the Arab world are the levels of access to information and the quality of education. Problems are currently found in curricula and teaching methods. Lack of access to computers, the internet, and electronic equipment, as well as teaching staff shortages, are the main problems. (UNESCO 2003).

Globalisation has made English the common medium of communication in most countries. According to Jones and Oberst (2007), restructuring and reformation is consistently required throughout the world. Higher education helps to prepare the professionals who will be responsible for handling markets and industries Jones and Oberst (2007). Thus, at this level, innovative technologies are needed to meet the requirements of globalisation. The Arab world has tried its best to promote engineering studies. They also tried to develop engineering programs that can be favourable for women, Jones and Oberst (2007).

1.1 Globalisation in Higher Education and Engineering Education

Globalisation, in the context of education, can be defined as the integration of information, ideas and knowledge. The term ‘Globalisation’ was primarily associated with economics. However, its usage is now common in the field of education, De Wit (2002). Globalisation brings the cultures of different countries together. When it comes to education, the effect of globalisation can be felt in terms of languages and technology; it is currently considered that globalisation has made English the common medium of communication in most countries, De Wit (2002). According to Zughoul (2003) the English language has become entrenched in the Arab world, especially after the Second Gulf War 2003.

New technologies are encouraging mergers at a global level. Industries and businesses are becoming international. Engineering problems of the next generation will deal with global issues, and solving complicated tasks. Future engineers must have the ability to combine their knowledge and make connections across different areas and disciplines. In order to become an integral division of the global environment, the educational institutes must modify academic programs, and consider their relevance to the requirements of the knowledge based society. Educators recommend applying the integrated approach for academic programs as common policy for studies, Stukalina (2007). According to Bey et al. (2008) the effects of globalisation can be observed in industry and trade. More technical expertise is needed join the globalised industry, in which the integrated technology exists. For this reason it is required that the educational system of engineering should be improved and developed. Students of engineering now face new responsibilities, duties and skills, and the ability to demonstrate competency are a pre-requisite for future employment. The engineers of the next generation need to be able meet the requirements that have been set by globalisation. Therefore, it would not be wrong to say that globalisation has totally changed the vision of engineering studies, Bey et al. (2008). Globalisation has also provided infrastructures to abate the solving of the complexities and uncertainties regarding any issue. It is of the utmost priority, therefore, that present teaching methods, which are based on outdated, rigorous approaches, be transformed and improved on. In order to produce a more creative, flexible dynamic that is both reflective and matched to current global needs, Zahlan (2007).

1.2 Bilingualism and Education

Bilingualism can be termed as having knowledge of two different languages. It does not mean that the person should be flawless in a given language; the point is to have reasonable knowledge of a language other than the mother tongue, Rasul (2006). When it comes to education, bilingualism is becoming required because of the competitive world today. It is the world of globalisation and it is necessary to meet the standards of today's industry and market. English has become the language that needs to be adopted by every country for international usage, Zughoul (2003). English Medium Instruction (EMI) means to mix the instruction of subject contents with foreign language teaching as well as learning instead of the first language, a foreign language is used as a vehicle for communication in different subjects, Vinke, Snippe and Jochems (1998). Implementing EMI will mean that the medium of instruction will be English, so that students can be taught according to international standards. EMI is especially necessary at the level of higher education because at this stage the students are on the next step to becoming professionals, needing practical skills for the real world. To implement bilingualism effectively, it will be required that courses be arranged in order to provide the students as well as the instructors with the proper knowledge of the language, Jusuf (2001). Many countries have implemented the EMI system, Schützenhöfer and Mathelitsch (2001). This change has resulted in growth and development in those countries. Therefore, having English as the medium of instruction should be promoted, as the returns of doing so are beneficial, Rasul (2006).

English Medium Instruction (EMI) for non-English is known as a bilingual teaching method. It is a recent emergence and is being implemented widely, Jusuf (2001). The main purpose of introducing this method of teaching is to provide the students with a mixture of language learning and other content area subjects. This with such certainty a good approach to making students learns another language, Jusuf (2001). A foreign language is required in order to improve levels of communication. According to Schützenhöfer and Mathelitsch (2001), the Austrian Ministry of Education supported and promoted this concept of implementing EMI. They concluded that there was a huge need to have foreign language learning in schools and other educational institutes. For this purpose English was chosen. It can be seen that Arab countries are now very much concerned with the developments of communication by using a foreign language. Using a foreign language is an efficient way of improving relations between different states. EMI has encouraged international co-operation and interaction in various education fields, Crystal (2003).

EMI is also helping to influence cultural awareness and learning abilities, Jia-Huey (2007). When first implementing this method, there are some issues that have to be addressed. First of all, it is necessary to develop an interest amongst students to learn a new language. Teachers should also give time to improve student's language learning skills. It is also necessary that efficiently trained staff be appointed. Obviously, students who are not very proficient in English will be unable to read books, journals and newspapers, therefore for those students it is necessary that appropriate methodology be developed, Schützenhöfer and Mathelitsch (2001).

2. QUALITY OF ENGINEERING EDUCATION IN THE ARAB WORLD

Arab countries initially found it is a great challenge to adapt to the global standard level of quality in the field of engineering, Shaw (2003). They tried to develop engineering programs that would be favourable for all, as they wanted more people to take part. Initial results were positive after the implementation of education programs that were aimed at improving the level of engineering studies. Some Arab countries are now able to produce skilled engineers in all areas. Such changes are important not only in the educational sphere; they reflect a desire on the part of those Arab countries to educate their people to move in the political, social and economical environment, Jones and Oberst (2007). The education of the next generation is very important for any country. Arabic countries have developed very rapidly, so the future of these countries totally depends on the education of its young people.

A report issued by the World Bank (2006) shows that majority of Arab countries, who benefited from oil and other natural resources over the past fifty years, primarily utilised foreign labour in the exploitation of such industries. Immigrant workers, especially in the engineering fields, were hired in large numbers to develop these industries, and the majority of specialists within these fields were non nationals. A study by Al-Jarf (2004) and other studies on teaching medical, science and engineering education in Arabic medium of instruction, including Muhaidib (1998) cited in, Al-Jarf (2004), showed that there was a negative effects on engineering graduates, this is because lack of translations to Arabic language, lack of scientific and engineering research in Arabic and that the industrial market preferably who knows English.

Arab countries need to develop a robust engineering curriculum. Most now are trying to overcome this issue by introducing courses that can enhance English proficiency abilities of students as well as instructors, Zughoul (2003). Arab governments are attempting to enhance education systems by looking at ways of meeting global challenges. Governments are concentrating on higher level education, with particular emphasis on the engineering sector and have reformed the systems so that can meet international requirements. Most of Arab higher institutes are concentrating on the implementation of EMI in educational system so that the graduates of engineering will be able to meet the challenges that are faced by engineers, Al-Jarf (2004). It can be observed in most Arab countries that foreign companies hold a large stake in their respective economies, whilst their own people only make investments. Restructuring is needed in the educational system of the engineering institutes in order to make positions in engineering and other higher education more accessible, available, and widespread. (National report presented to UNESCO 2008).

3. COUNTRIES IMPLEMENTING EMI IN HIGHER EDUCATION SYSTEMS

Implementing EMI is the current trend that is being followed widely. This section discusses some of the countries that have adapted EMI in their educational systems:

3.1 Asia

EMI has been in use in Indonesian higher education for some time, and many universities have developed international programs using EMI. Their goal is to be bilingual; English was being used as the second medium of instruction in its classes by the academic year 2004/2005, Jusuf (2001). There are four factors supporting the possible implementation of EMI at Indonesian universities. These are as follows:

1) Bilingualism aids communicative and societal advantages. 2) English plays an important role in helping motivate students and teachers in learning the language. 3) EMI would help students as well the teachers in exploring English and having more chances to learn it well. 4) Literacy

skills and strategies learned in the native language, Indonesian, is transferred to a second language, namely, English.

EMI is growing very popular in the Indonesian universities on a daily basis. The advantage of utilising global opportunities is a priority for Indonesia's universities. Being able to access up-to-date information, either through printed materials or online, as well as being able to engage in international dialogue is critical for those institutes. Thus, EMI usage has been increased and results show that such methods have improved proficiency in the English language, Jusuf (2001). The basic goal is to be able to write and communicate in two languages. However, EMI in Indonesia is not as simple as it seems. All the aspects of EMI should be considered before making a decision to adopt it. The aspects that should be considered before adopting are opportunities of EMI, threats of EMI, problems faced by EMI and possible solutions.

English is also regarded as an important language in Korea. Korean universities have implemented EMI in order to improve their education level and meet the requirements of today's competitive environment. In the majority of Korean institutes, the lectures are conducted in the English language rather than using their native tongue, Kim and Shon (2009). EMI is being used in mostly higher level education courses such as engineering and science. English is necessary for maintaining international dialogue and for keeping pace with the changing standards of the industry. EMI is widely integrated in to the syllabus of engineering in Korean universities. EMI is being implemented in such a way that the students can increase their knowledge of the language as well as the subject content. As a result, by providing sound knowledge regarding the language, EMI courses in Korea are improving the quality of education given at those institutes, Kim and Shon (2009). Nonetheless, Korean universities have had some difficulties while implementing EMI. One major problem was the shortage of lecture material. Some instructors did not have a robustly proficient knowledge of English. In such cases the instructors were limited to the available content and could not give examples or references related to the topic. This resulted in some students misunderstanding lecture content.

With time, though, EMI implementation has improved and has been an overall success. The reason for this high usage of English in the lectures is because educational institutions in Korea are determined to meet the standards of international universities. Whilst there have been problems in the past, the advantages are presently numerous to the point where students now graduating can meet the global industry standards, Kim and Shon (2009).

3.2 Europe

The proposal to use EMI at Dutch universities was first introduced in 1990 Hagers (2009). Efforts are being made to improve the quality of teaching by increasing the level of English language instruction. At first, the level of higher education in Netherlands was not impressive enough to convince people from other countries to enrol in Dutch universities, De Wit (2002). The reason for the low popularity of the Netherlands's higher education institutes was mainly the language problem. Dutch was the sole language being used in those institutes, a language which many foreigners are unfamiliar with.

After observing the emerging competitive environment, these universities started to introduce courses that helped in improving the level of English language. Higher education institutes also started introducing courses that were being taught in international standard. The steps taken by the Dutch helped improve the overall level of education and eventually aided in their integration with international educational institutions. The Dutch institutes have implemented the EMI in their educational systems and now they are giving priority to English in high levels of education. EMI is now also being implemented in other European countries like Denmark, Norway, Finland, Germany, Austria and Sweden, De Wit (2002).

4. IMPLEMENTING EMI IN ARAB ENGINEERING EDUCATION

Most engineering education students in Arab countries have learned English as a subject since the age of twelve in high school, and have continued learning the language until on average twenty three, Zughoul (2003). However, implementing EMI in Arab engineering education by using the immersion method is not in use. In this method, the language is not the subject of instruction, but rather is the vehicle through which subject areas are taught. Most immersion programs include math, science, social studies, and health taught in the target language, Chamot and El-Dinary (1999). A study by Al-Jarf (2004) in some Arab countries showed that 96% of Jordan University students and 82% of King Saud University believe that EMI is more appropriate for engineering education, medicine and science.

4.1 Total immersion.

Total immersion programs are common in areas in which students encounter bilingual and bicultural experiences on a daily basis. For example, many schools in Canada have total immersion French programs for English speaking students, because English and French are both official languages in that country Bostwick (2003). The general lack of English language proficiency and communication among students and teachers in Arab higher education system, Rababah, (2003) and Al-Jarf (2004) and high cognitive skills required for higher education tasks would make total immersion hard to implement. Therefore, partial EMI is a viable option, Jusuf (2001).

4.2 Partial immersion.

Partial immersion programs dedicate about half of the class time teaching the subject matter in the target language. Reading, writing, and spelling are taught in the students' native language, while the other subject material is taught in the second language, Chamot and El-Dinary (1999).

According to Bostwick (2003) students in partial immersion programs are expected to become proficient in the second language to a lesser extent than students who are in total immersion classes. Nonetheless, they are still expected to become proficient in the subject matter appropriate to their grade level, comparable to students who receive instruction in their native language. Students in partial immersion classrooms are also expected to gain a heightened understanding and sensitivity for the other cultures with which the target language is associated, Jusuf (2001).

5. CONCLUSION

Globalisation has made the world a global village. To achieve a high standard of engineering education in Arab countries, new technologies and an updated syllabus must be implemented. EMI is an innovative bilingual method, which influences general proficiency in English language and can improve engineering skills in the Arab world. EMI is still a new method, but one which will become more widespread. It will prepare professional engineers to a higher standard, and ultimately will help improve the quality of life in the future. Partial immersion program is the best option for implementing EMI in engineering study programmes in the Arab world. For now, the limitations of English language use amongst students' means that EMI will need to proceed on a smooth, step by step basis.

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EDUCATING EIRGRID'S POWER SYSTEM ENGINEERS TO FACILITATE A SUSTAINABLE FUTURE - A PARTNERSHIP OF ACADEMIA AND INDUSTRY

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ABSTRACT

This paper describes the role and activities of EirGrid plc, and the skills and knowledge required of its circa 150 engineers in order to support EirGrid plc's role of ensuring competitiveness, sustainability and security of electricity supply across Ireland. The education of engineers is a life-long enterprise in which academia, industry and the engineer all have a responsibility. The paper focuses on the different interactions among EirGrid TSO (Transmission System Operator), Academic Institutions and students which influence the education of engineers and the direction and industry focus of research. The paper discusses how educating engineers continues as lifelong learning and describes initiatives including EirGrid TSO's Graduate Development Programme and commitment to Continuing Professional Development (CPD) which facilitate the continued learning for engineers.

Keywords: TSO, Industry, Partnership, Professional Development, Skills

INTRODUCTION

EirGrid plc is the commercial state-owned company established under Irish and EU law to carry out the role of independent Electricity Transmission System Operator (TSO) and Market Operator (MO) in Ireland. Through System Operator Northern Ireland (SONI), which became part of the EirGrid Group in March 2009, it is also the Electricity Transmission System Operator and Market Operator in Northern Ireland. As transmission system operator, and market operator, EirGrid plays a key role in ensuring the competitiveness, sustainability and security of electricity supply across the island of Ireland.

EirGrid as an organisation relies on having highly skilled staff in a variety of disciplines. There is a high engineering content in its activities and to succeed in its roles requires having a significant number of skilled engineers. Currently EirGrid has more than 150 qualified engineers (approximately 50% of staff). EirGrid has a strong interest in the quality and supply of engineering graduates. It has a number of initiatives in place to work in partnership with universities to strengthen links between universities and the industry. This paper describes EirGrid's activities and its need for engineering skills. It describes how the partnership initiatives in place contribute to the ability of EirGrid to develop the depth of engineering skills and knowledge required in order to fulfil its key role.

OVERVIEW OF EIRGRID'S ACTIVITIES

As transmission system operator, EirGrid is responsible for operating a safe, secure, reliable, economical and efficient power system 24/7 for the benefit of our customers, the users of the system in Ireland and Northern Ireland. The grid comprises the meshed system of transmission stations and of lines and cables at and over 110,000 volts as shown in Figure 1. EirGrid is also responsible for providing transparent, non-discriminatory transmission system access to generators (conventional and renewable), demand customers and interconnectors and for planning the development of the system in Ireland. SONI manages the power flows on the Moyle Interconnector between Northern Ireland and Scotland. The Single Electricity Market Operator (SEMO, a joint venture between EirGrid and SONI) operates the Single Electricity Market which is the wholesale electricity market across the two jurisdictions on the island of Ireland. The Market Operator settles all trades made in the electricity market and administers all payments made to and received from generators and suppliers. A single scheduling and dispatch tool is utilised to minimise generation costs in the single electricity market.

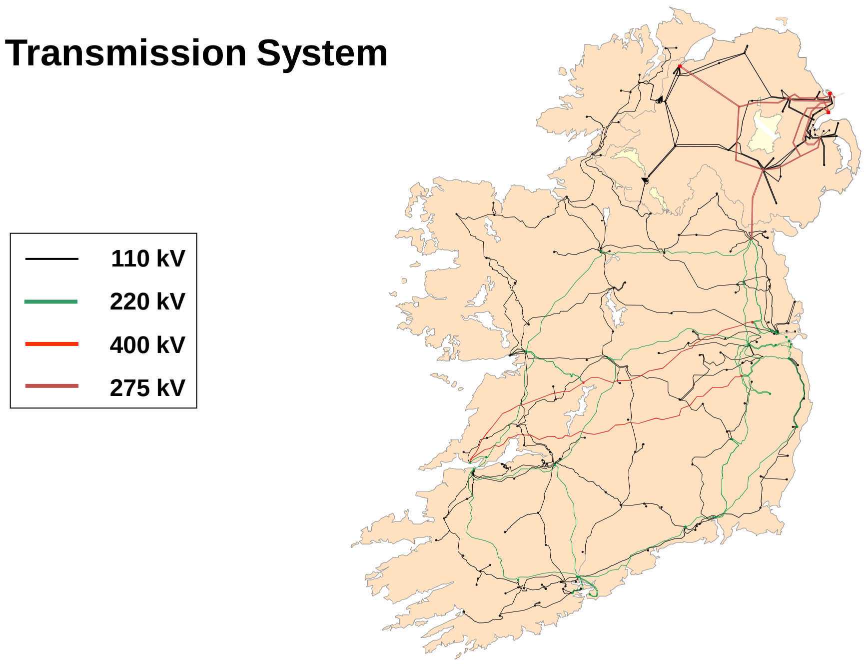

Figure 1: The Transmission Grid

Ireland's renewable energy potential is one of the finest in the world and the government is fully committed to exploiting this abundant resource to reduce Ireland's dependence on fossil fuel imports. Ireland's target is to have 40% of electricity generation from renewable energy by 2020 which will involve accommodating one of the highest levels of wind generation in the world and will position Ireland as a world leader in the integration of wind energy onto a small island system. There are a number of initiatives in place to enable this target to be met and EirGrid is being proactive in identifying and solving issues associated with integration of renewables.

EirGrid plays a key role in delivering on the Irish government's economic recovery plan "Building Ireland's Smart Economy – A Framework for Sustainable Economic Survival". It is developing grid infrastructure in Ireland to put in place a grid which will be able to accommodate Ireland's renewable energy targets and be a platform for economic recovery in a timely efficient manner, balancing need for infrastructure with impact on price of electricity, the environment and the community. EirGrid is also building an interconnector between Ireland and Wales to strengthen Ireland's links with the Great Britain energy market, to facilitate competitive export and import of electricity and to increase security of supply.

ROLE OF ENGINEERING IN EIRGRID

EirGrid employs over 150 engineers in a wide variety of roles. Engineers are involved in the planning of the Transmission network and in the planning of access to the network. Engineers are involved in the control and operation of the Power System and in the operation and development of the Single Electricity market. Engineers are involved in the protection and maintenance of the power system and in the management of large construction projects. Engineers are involved in management of customer connection to the Transmission System and in the commercial and pricing functions.

A wide variety of highly specific skill sets is required of its engineers, some of which are instilled by the universities, but much of which is developed through training and development within the organisation. For example, an engineer working in the control and operation of the power system needs advanced knowledge of power systems. An engineer working in the management of large projects typically needs strong project management skills and may need negotiation expertise and the ability to deal effectively with 3rd parties. Engineers involved in the commercial and pricing functions of EirGrid require contract management skills, knowledge of power systems and an understanding of the Electricity Regulatory environment. Apart from the technical skill sets required, EirGrid has identified a number of personal and interpersonal skills and behaviours which are required of all its professionals. These would include good analytical, data acquisition and problem solving capabilities and good communication and interpersonal skills, to name but a few. In addition, EirGrid looks for the ability to work effectively as part of a team, to be capable of self-motivation and, at the higher levels of the organisation, the ability to lead others effectively. The skills model that meets the needs of EirGrid as a business is closely aligned with the models discussed below.

Shuman et al (2005) outline and discuss the skills that ABET (the Accreditation Board for Engineering and Technology) defined originally in 1996 and updated in 2004. Along with the "hard" skills such as those required to identify, formulate and solve engineering problems and the ability to use the techniques, skills and modern engineering tools necessary for engineering practice, a set of "professional" skills has been identified. These skills include:

- The ability to function on multi-disciplinary teams
- An ability to communicate effectively
- A recognition of the need for, and an ability to engage in lifelong learning
- An understanding of professional and ethical responsibility
- The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental and societal context and
- Knowledge of contemporary issues.

With special relevance to the last three points above, Professor Barbara Wright (2009) describes the need to truly attend to the gap between knowledge and training in the field of engineering. She believes that flexibility of approach and lateral thinking should be encouraged in all professional education. In addition, she believes that engineers, once established, should be more willing than has been the case so far to engage in politics, especially in the later stages of their careers. As she states "the complexity of decisions on which politicians are currently called upon to judge is such that there is a crying need for greater levels of expertise and competence. If engineers fail to rise to this challenge, the gap between the real and the ideal will continue to make itself felt and humanity will be the victim".

It can be argued that engineers today not only need the technical tools of their profession, they need another set of tools that allow them to bring their technical skills into most effective and efficient use. It is our belief that these skills, while introduced at undergraduate level, will need a lifetime of development. We would feel that the recognition of the need for and the ability to engage in lifelong learning, plus a willingness to be self-reflective, are probably the most important indicators of a graduate's potential to develop, and we look for these attributes in applicants. They are by no means universally present. We believe that EirGrid, by effective partnership with academia, maximises the opportunity for its engineers to develop in line with their own and with the organisation's requirements. Charles M. Vest (2005) describes the new world of engineering pedagogy as preparing engineers for " an understanding of what engineers actually do; they must write and communicate well; must think clearly about ethics and social responsibility; …and must know how to conceive, design, and operate engineering systems of great complexity. They must also work within a framework of sustainable development, be creative and innovative, understand business and organizations, and be prepared to live and work as global citizens. That is a tall order . . . perhaps even an impossible order". Our thesis, and one that we develop in this paper, is that this cannot be achieved by academic institutions alone, but that instead industry must play its part and be treated as a respected partner.

PARTNERSHIP OF INDUSTRY AND ACADEMIA

Engineers experience a lifetime of learning in the course of their professional lives. The task of teaching engineers begins with formal learning in the schools and universities, and continues throughout their working lives in the form of continuing professional development (CPD), which will involve on-the job training, formal learning and further education, though this list is not exhaustive. Responsibility for enabling lifelong learning lies with both Industry and Academia. For the partnership of Industry and Academia to be successful, i.e. to produce the kinds of engineers capable of doing the job required, both sides of the partnership must have the same picture of what is required and must be very clear of its part in the process. For this to happen, there must be regular and open dialogue between all parties, and clear channels of communication. At the bottom line, industry needs to be able to access top quality graduates who not only have the basic technical skills of their specialism, but technical skills that are relevant to the future environment in which they will operate. In addition, graduates need to have an understanding of the professional and interpersonal skills they will need in order to make the best use of their technical skills. Industry needs to communicate to academia in a timely fashion its current and future needs of engineering graduates.

The current situation – EirGrid TSO and Academic Institutions

EirGrid TSO has a number of planned parallel interactions with Academic Institutions across the academic time-frame which influence both the education of engineers and the direction and industry focus of research. There are interactions with universities at student placement level, graduate recruitment level and post-graduate Research & Development level. In addition, there are various contacts at different levels in the organisation, through, for example, personal contacts with alumni and individual lecture contributions,.

EirGrid TSO is a significant employer of engineering graduates. At the moment, we adopt a two-pronged approach to recruiting graduates. We hire newly-qualified graduates and we also provide placement opportunities for undergraduates that will identify suitable graduates for hire on graduation.

EirGrid TSO’s hiring strategy is to hire top graduates across all engineering disciplines, and develop their Power System knowledge and experience in-house. One of the drivers of this strategy is the limited emphasis on Power System Engineering in undergraduate education. EirGrid TSO has implemented a Graduate Development Programme (GDP), which offers new graduates a number of placements across the organisation, a comprehensive training programme and an experienced mentor for the duration of the programme. A strong panel of engineers has been chosen and trained to act as a graduate hiring panel, contributing to their own professional development. Generally speaking, graduates, while excellent in overall quality, come to EirGrid TSO with very little Power System knowledge or experience, and the task of growing this expertise is undertaken by the organisation.

Since 2007, EirGrid has hired ten engineering graduates for our Graduate Development Programme, and will hire two more graduates this year. The standard of graduate is excellent, and the placements and the mentor are seen as particularly developmental by the graduates. EirGrid has also hired a number of engineering graduates into specific roles, but is committed to providing mentors to these graduates. In addition, it is recognised in the organisation that rotating less experienced staff around the organisation bears dividends in both personal and organisational terms, and is committed to providing rotational opportunities when and where possible, though it is not guaranteed within a specific timeframe.

Since 2007, EirGrid TSO has adopted a more proactive and focused approach to bring placement students into the company. A placement scheme was developed offering undergraduate engineers the opportunity to work with EirGrid for six months as part of their degree courses. College lecturers supervise the students and visit both the student and EirGrid TSO to make sure that the placements run smoothly. The panel of engineers referred to earlier also acts as student supervisors for the duration of the placements. This in itself has offered development opportunities for the panel members. In each of the past two years up to ten students from a variety of universities have spent their placements in EirGrid TSO. These placement opportunities allow undergraduates to begin to develop their own professional skills, in terms of working in teams and communicating effectively, in understanding the impact of engineering solutions and in beginning to understand contemporary issues. In addition, it has provided an opportunity for EirGrid to give feedback to the academic supervisors on the content of the course and on the quality of the students. There is enormous value for students in being able to participate in engineering practice, and bringing that understanding back to their formal studies.

EirGrid TSO has a number of Research & Development interactions with Academia and is sponsoring post graduate research in universities in areas such as grid integration of renewables and improving system modelling. In deploying the funding, one objective is to collaborate with Irish academic institutions with active relevant research schools, to influence the direction and industry focus of research and stimulate interest in these fields among students. We interact with a number of institutions including U.C.D., U.C.C. and D.I.T., usually by finding individual research projects, or by sponsoring prizes in particular programmes such as U.C.C's Masters programme in Sustainable Energy.

Figure 2 below demonstrates the ways in which EirGrid TSO interacts with undergraduates and post-graduates who are actually within the education system.

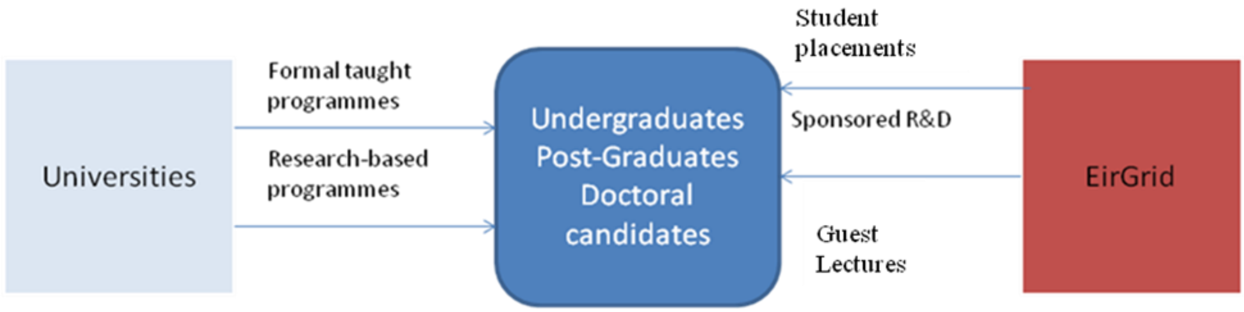

Figure 2
Interaction of EirGrid with Universities on Undergraduate / Post-Graduate students

The current situation – CPD in EirGrid TSO

Through CPD, EirGrid TSO encourages its engineers to take personal responsibility for their own rounded, professional development, while ensuring that the organisation will have in place the skills and knowledge to continue to meet its responsibilities and objectives. EirGrid TSO is a CPD-accredited organisation with Engineers Ireland. In order to achieve accreditation, EirGrid TSO has demonstrated the existence and efficacy of a number of systems that together support ongoing professional development of all staff. These systems include a Graduate Development Programme, a commitment to Knowledge Management and a Performance Management system. EirGrid has developed a Staff Competency framework and is currently implementing a wide-reaching staff development programme covering all competencies on the framework. Through CPD, we hope to encourage more of our engineers to achieve CEng status. Many of our engineers would be working towards MEng or equivalent programmes, and our challenge with CPD is to encourage our engineers to focus more on seeking and using developmental opportunities that are work based or soft-skills based, rather than relying solely on academic development.

Ongoing Education Support is widely provided. As well as supporting a range of technical Post-Graduate diplomas and Master's degrees, EirGrid TSO is supporting both PhD and MBA students. EirGrid TSO invests enormously in ongoing technical training sourced from a wide variety of providers in the industry and across the globe. Knowledge sharing throughout the organisation is facilitated by internal seminars, Power Hours and by programmes such as The Introduction to Power System Operation (IPSO), designed, developed and delivered by subject matter experts across the organisation. A mentor programme for graduate engineers is in place and mentoring is being rolled out across the organisation. A CPD re-accreditation audit was carried out by Engineers Ireland in December 2008. Engineers Ireland spoke with a number of engineering staff, and evaluated EirGrid's CPD systems. They concluded that CPD is core to EirGrid's Business Strategy with maintenance and development of EirGrid's organisational capability a key element of the current Business Strategy.

EirGrid TSO participates actively in CIGRE, the International Council on Large Electric Systems. This is one of the leading worldwide organizations on Electric Power Systems, covering their technical, economic, environmental, organisational and regulatory aspects.

Over the years, EirGrid TSO (and its former embodiment ESB National Grid), has had a history of providing senior experts to serve on CIGRE committees and many staff members have also been involved in the work of its working groups, thus providing development opportunities for staff at all levels in the organisation.

Figure 3 illustrates how over time, universities and industry have important roles to play in the long-term development of engineers engaged in a key industry. The message of the figure is that over time, an employer such as EirGrid has increasing responsibility to provide development opportunities for engineering staff.

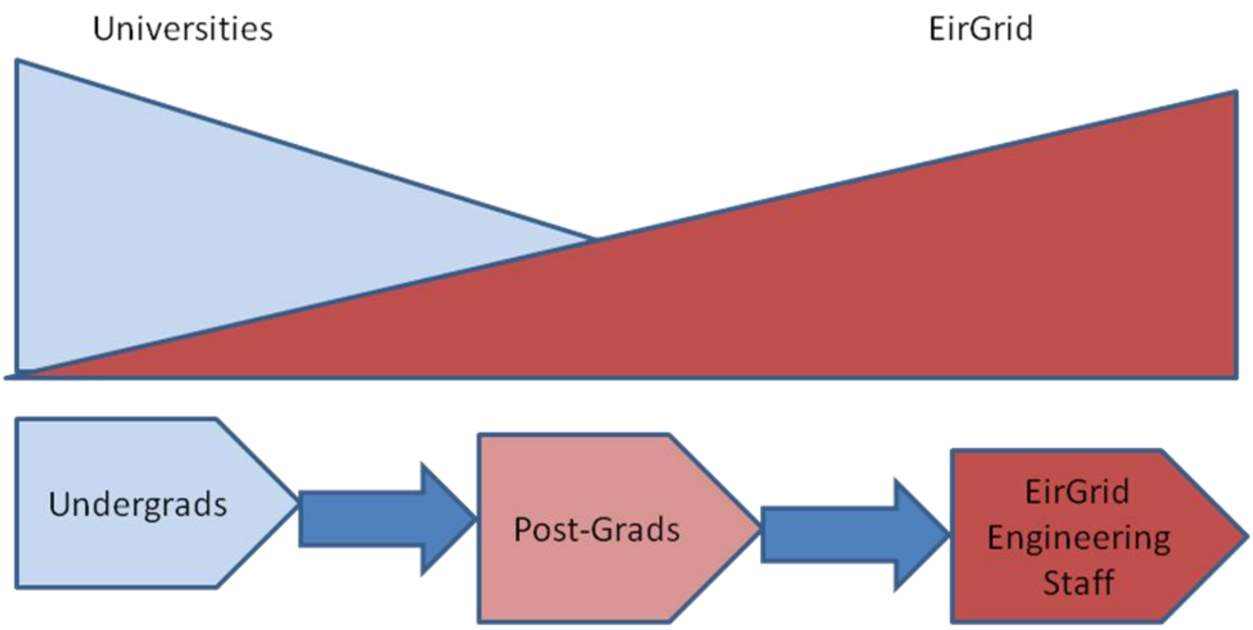

Figure 3
Overlapping influences over time

CONCLUSION

Education of the new engineer involves a long-term partnership of academic institutions and industry. EirGrid TSO's approach is to work in tandem with relevant academic institutions to both influence curricula and support research and development, to provide job opportunities for graduates, and to build capability to meet the wider needs of the Island of Ireland in the arena of energy and power. It is vital that academic institutions and organisations like

EirGrid TSO understand their respective roles in this partnership and regularly question the effectiveness of the partnership in meeting the wider needs of the island of Ireland.

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A NEW GRADUATE COURSE TEACHING CHEMICAL ENGINEERING IN USE OF RENEWABLE RESOURCES

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Abstract: Fossil fuel resources such as natural gas, oil and coal will be used up in the future. Moreover, the current use of these resources has led to environmental risks such as global warming. Energy and materials based on fossil resources must be produced from other substitute resources in order to suppress the carbon footprint that has been planted, and maintain and improve the current life styles of human beings in the future. Renewable resources, or biomass, are one of the substitutes from which energy including liquid fuel, and materials can be produced.

To bring students the awareness of utilizing renewable resources, a new graduate course, entitled *Chemicals and Energy from Renewable Resources*, has been implemented in the Department of Chemical Engineering, University of Saskatchewan lately. This course is divided into two parts. Part one deals with the basic processes such as gasification, pyrolysis, catalytic conversion and synthesis, separation unit operations in chemical and energy production from renewable resources. The content of this part includes reactor design, catalytic chemical engineering, and separation processes. Part two presents case studies of processes that produce energy and chemicals from biomass. Attentions are given to technology development, potential emission and pollution controls and production economics.

The format of the course includes lectures, class discussion, literature review, project oriented assignments and student presentation. The case studies are closely combined with the research work of the students. The course has been welcomed not only by the graduate students from this department but also those from other departments and colleges.

Keywords; engineering education, renewable resources, chemical engineering, sustainability awareness.

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1. INTRODUCTION

As it is realized that the use of fossil fuels has created environmental problems and led to sustainability concerns, more attention has been drawn to the utilization of renewable resources, attempting to produce chemicals and energy with more environmentally friendly, more carbon-neutral, and less hazardous processes. Unlike processes producing chemicals and energy from fossil feedstock, special considerations have to be taken when the feedstock becomes renewable resources. In addition to the preparation of raw materials, the chemical routes of producing the same products can be different. For example, fuels such as gasoline and diesel are produced in refining crude petroleum oil, whiles diesel is produced by transesterification of bio-oil and gasoline is produced by Fisher-Tropsch synthesis route from the synthetic gas generated from biomass gasification. Students, especially graduate students, working in the relevant disciplines must be aware of these differences and be prepared for the change when renewable resources are used. To meet the needs from students in this regard, a new graduate course in chemical engineering entitled *Chemicals and Energy from Renewable Resources* has been created and has been taught for five years in the University of Saskatchewan.

The purpose of this paper is to share how the course was initiated, developed, and offered, what contents are included, and the feedback of the students who have taken the course.

2. COURSE DEVELOPMENT

In 2005/06, a new reading course was initiatively offered for graduate students in the College of Engineering at the University of Saskatchewan. The course wanted to bring to students the awareness of using renewable feedstock to produce commodity chemicals and energy and its environmental and sustainable benignity. For the first three years, the course was offered as a reading class. Then, the College of Graduate Studies and Research of the University of Saskatchewan approved this course to become a regular graduate course. Unlike a course in which giving lectures accounts for the main class events, this course combines lectures, class discussions, student presentations, and term paper assignments. Lectures that the instructor presents offer introductory concepts and information associated with the utilization of renewable resources and its environmental footprint, and examples of such a production process with considerations of sustainability and environmental friendliness. Chemical engineering principles and unit operations with consideration for the specialties related to the utilization of renewable resources are also included in lectures. In the events such as class discussion, student presentations and term paper assignments, students are encouraged to involve their ongoing or future research topics. If the research area is associated to using renewable resources, students can bring the topic to the class. If the research is not related, they can add renewablility or sustainability elements in their research topics and present the work in this class. This way, students not only learn from the lectures that the professor presents but also learn from the work of their fellow students in class. To evaluate the performance of students in class, students are required to give two powerpoint presentations and submit two term papers. The assignments like these also offer opportunities for students to improve their public speak ability and technical writing ability. The first presentation and term paper discuss the general overview of a topic associated with the utilization of renewable resources, and the second set deals with the processes and operations of the utilization.

To provide more information of how this class is operated, the latest course syllabus is given in the attachments.

Table 1 Student enrolment and home departments

School year	*Enrolment number*	*Home department and student number*	
2005/06	1	Agricultural and Bioresource Engineering	1
2006/07	3	Chemical Engineering	3
2007/08	6	Agricultural uateand Bioresource Engineering	2
		Chemical Engineering	4
2008/09	8	Chemical Engineering	8
2009/10	15	Agricultural and Bioresource Engineering	1
		Chemical Engineering	10
		Food and Bioproduct	4

3. STUDENT ENROLMENT AND DISCIPLINES

From 2005/06 to 2009/10, thirty-three students from the Department of Chemical Engineering and the Department of Agricultural and Bioresource Engineering in the College of Engineering and the Department of Food and Bioproduct in the College of Agriculture and Bioresource have chosen this course. The enrolment is listed in Table 1. It can be seen that the course now becomes more popular to graduate students from a variety of disciplines. It has been realized that the appropriate class size is 10 to 15 students from different disciplines so students could have sufficient opportunities to learn from each other under the format of this course. A small class will not allow delivering this strength. If the class is too big, the time given to a student for class discussion, presentation, and student-with-professor meetings would be limited.

4. TOPICS AND PROJECTS

Table 2 lists the topics involved in the past five years. The projects of the course discuss every aspect of production from renewable resources, from feedstock to products, from processes to operations, and from fundamentals to applications. Some present broad perspective of a topic, some focus on particular issues of a topic. Table 2 indicates that topics of biofuels production from renewable biowaste resources are heavily covered by student projects. This is because there is a large research group led by a faculty member in our department who is the Canada Research Chair in Bio-Energy and Environmentally Friendly Chemical Processing. The feedstock resources include lignocellulosic mass such as agriculture residue and wood residue, green seed canola oil, wastes from slaughterhouses, algae, and pongamia. Products from the topics involve hydrogen, syn-gas, bio-oil, ethanol, and biodiesel. The routes include gasification and pyrolysis, hydrolysis and fermentation, and transesterification. Materials with particular functions developed from renewable resources are also presented. The examples are adsorbent from barley straw and bioactive lipids from diary waste streams. Topics involving new ideas are ion-exchange resin as transesterification catalysts, microbial fuel cells, and value-added synthesis from by-product glycerol. Projects associated with sustainability issues such as hydrogen production from industrial waste H2S and geothermal energy are also seen in the list.

Table 2 Topics and projects undertaken

School year	*Project title*
2005/06	**05A.** Chemical and energy from biomass
2006/07	**06A.** Hydrolysis as a method to generate renewable energy
	06B. Fundamentals of clean energy: gasification and pyrolysis
	06C. H2S sorbent regeneration for more sustainable operation
2007/08	**07A.** Energy from renewable hydrogen
	07B. Analysis of meat and bone meal as energy feedstock
	07C. Bioethanol production from sugar cane in Brazil
	07D. Biomass and gasification
	07E. Fundamentals of syn-gas production from crop residues
	07F. Hydrogen recovery from biomass gasification
2008/09	**08A.** Nickel biosorption using barley straw
	08B. Ion-exchange resins as catalysts in biodiesel production
	08C. Electricity production with microorganisms via a fuel cell
	08D. Bio-oil upgrading processes
	08E. Hydrogen production from industrial waste H2S
	08F. Hydrogen production from renewable biomass through gasification
	08G. Bioethanol production system from wheat straw
	08H. From biowaste to electricity using microbial biofuel cell
2009/10	**09A.** Lignocellulosic bioethanol production processes in Western Canada
	09B. Biodiesel production from green seed canola oil in Canada
	09C. Microbial fuel cells for energy production from renewable biomass
	09D. A bioactive lipid, sphingomyelin, from diary waste streams
	09E. Fermentable sugars from lignocellulosic biomass
	09F. Bioethanol production from lignocellulosic biomass
	09G. Hydrogen production routes from sulphur-containing industrial wastes
	09H. Bioethanol production through tranesterification of rapeseed and canola oils
	09I. An industrial scale microbial fuel cells
	09J. Hydrogen production from biomass gasification
	09K. Biodiesel production from algae
	09L. Production and separations of positional isomers of hydroxystearic acid
	09M. Geothermal energy and its recovery
	09N. Biodiesel production from pongamia
	09O. Value-added utilization of glycerol in biodiesel production

5. STUDENT FEEDBACK

Student feedbacks are regularly invited by formal or informal questionnaire at the end of class every year. The questions used for 2009/10 year are the following:

1) Why would you have considered taking this course? If you have 2 or 3 reasons that helped you have selected this course, what are they?

2) Before you took this class, what were your expectations of learning in this class? After taking this class, have you learned what you had expected? If there is any difference between your expectations and what you have experienced and/or any disappointment, what is it?
3) In terms of renewability and sustainability, have you been more aware of them after taking this course? What is your opinion on utilization of renewable resources? Have your opinion changed after taking this course?
4) Do you pay attention to the United Nations Climate Change Conference in Copenhagen and do you have a hope on it (optional)?

Typical answers to question (1) include getting to know the up-to-date knowledge of using renewable resources and its importance to a sustainable human society, combining course work and research work in one, and the opportunity of improving the oral and writing presentation skills. To question (2), most students thought their expectations in learning had been met after taking this course. Some provided suggestions in how to improve the course contents for the next year. For instance, it was suggested that economic feasibility should be included when a process of using renewable resources is taken into consideration. Others hoped we should look at the sustainability of the new technologies and avoid creating new troubles resulted from the ignorance of this. 100% of the participating students were positive to question (3), giving views of their own on sustainability of economic activities and renewability of resources. However, what surprised me was that half of the participants did not think the Copenhagen conference can do anything helpful to the world situation in environmental problems.

6. CONCLUDING REMARKS

The utilization of renewable resources to produce chemicals and energy becomes more and more important when environmental friendliness and sustainability are addressed. For the same production, there are special technological considerations when renewable resources are used. Students have to be prepared for the change. This new graduate course meets the needs from this regard. The untraditional format of the course combines lectures and project based assignments, allowing students to learn not only from instructor but also from their own work. The course directly brings graduate students to the frontier of the research and development of the technologies of using renewable resources as feedstock for chemical and energy production. I believe with the training offered by this course students will be prepared to face the challenges in the transition of replacing fossil feedstock with using renewable resources for a better environment and sustainable economy.

(Attachment: Course syllabus of 2009/10 version, page 6-8)

UNIVERSITY OF SASKATCHEWAN

COLLEGE OF ENGINEERING
DEPARTMENT OF CHEMICAL ENGINEERING

ChE 888.3 – Chemicals and Energy from Renewable Resources

Winter 2009/10

Instructor: **Hui Wang**
1C126 Engineering Building
57 Campus Drive
Phone: 966-2685
E-mail: hui.wang@usask.ca

Lectures: Eng 2C90: T, Th 8:30-9:50 am

Reference Books

- Chemicals and materials from renewable resources / Joseph J. Bozell, editor
- Allen, David T; Green engineering : environmentally conscious design of chemical processes,
- Green chemical syntheses and processes / Paul T. Anastas, Lauren G. Heine, Tracy C. Williamson, [editors]
- Green chemistry : challenging perspectives / edited by Pietro Tundo and Paul Anastas
- Handbook of green chemistry and technology / edited by James Clark and Duncan Macquarrie
- Other materials from journal papers

Website:

Assessments:

Term Paper #1: **Fundamentals of a Process that Uses Renewable Resources**

Presentation	20%
Paper	25%

Term Paper #2: **A Process that Makes Use of a Renewable Resource**

Presentation	20%
Paper	25%
Class Discussion	10%
Final Exam	

The mark distribution is only approximate. Final grades will be assigned at the discretion of the instructor subject to the University Council and College Regulations on Examinations.

Objectives:

The objectives of this course are as follows:

1. To introduce a manifest perspective of the processes that produce chemicals or/and energies from renewable resources.
2. To study the application of the fundamental principles of chemical engineering in the processes that generate chemicals or/and energies from renewable resources.
3. To bring the students to the frontier of studies and research on the processes that generate chemicals or/and energies from renewable resources.

By the end of this course, it is expected that students are stimulated with a broad interest in the research areas of the production of chemicals and energies from renewable resources.

Description:

Fossil fuel resources such as gas, oil and coal will be used up someday in future. Energies and materials based on such resources must be produced from other substitute resources in order to maintain and improve the current life styles of human being. Renewable resources, or biomass, are one of these substitutes from which energies and materials can be produced. Saskatchewan is a province that has abundant renewable resources.

Processes that produce energies and chemicals from renewable resources consist of basic chemical processes such as combustion, gasification, pyrolysis, catalytic conversion and synthesis, and separations. When dealing with these processes with renewable resources, fundamental principles of chemical engineering are applicable but special attentions have to be paid. Among these processes, some produce energy, fuel and other chemicals simultaneously, and others just generate particular chemicals or materials. Fuels and chemicals can be synthesized from synthesis gas, carbon monoxide and hydrogen, which are produced from the gasification or pyrolysis of biomass; or they can be processed from the renewable feedstock directly.

This course is divided into two parts. Part one deals with the basic processes such as gasification, pyrolysis, catalytic conversion and synthesis, extraction, and etc in the production from renewable resources. The content of this part includes reactor design, catalytic chemical engineering, and separations. Part two presents case studies of processes that produce energy and chemicals from biomass. Emphasis and attention will be directed to the development of such processes that consume only renewable raw materials and energy, make highly efficient use of raw materials and energy, reduce or eliminate the use and generation of hazardous substances, and reduce or eliminate the release of substances harmful to humans and the environment.

Detailed Course Outline:

Approximate Lecture or Class Discussion Hours	Information
1	Introduction to Green Chemistry and Chemical Engineering
2	Renewable Resources and environment Awareness
2	Gasification and Pyrolysis
2	Separations
2	Processes Using Synthesis Gas
3	Application of Catalysis
12	Chemicals from Renewable Resources
- 3	- Fuels
- 3	- Polymers
- 3	- Other chemicals
- 3	- Energy (Electricity, etc)

Students should be aware of and follow the new University of Saskatchewan Academic Honesty/Dishonesty definitions, rules and procedures that are available on the web at www.usask.ca/honesty.

USING VIDEO REPORTS TO PROMOTE ACTIVE ENGAGEMENT IN LEARNING

Peter Willmot* and Sarah Bamforth

Loughborough University

Abstract: The expectation of today's paying customers is of 'teaching' not 'learning' and sadly, even a mild spell of disengagement can quickly lead to an unwelcome request for a course transfer. This paper describes how rising wastage rates encouraged a large engineering department to review the first year curriculum and this resulted in the introduction of an innovative new problem-based module sitting alongside traditional engineering units. The new module features several team project assignments and a series of skills workshops. All the learning scenarios were designed to improve study competences, to add interest and enjoyment and to address the gulf in attitude to learning that exists between staff and students. This paper concentrates on just one of the assignments, which was designed to encourage teamwork and improve fundamental knowledge of machines and systems. It shows, through survey data, how a novel video reporting approach that has proved both exciting for the students and efficient for staff was used to stimulate, present and assess the learning.

Keywords; PBL, Assessment, Video, Engagement, Teamwork
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1. INTRODUCTION

1.1 Realisation

The gulf between the educational methods in UK secondary and tertiary education has never been wider. Students arrive at university, increasingly driven by marks and with the expectation of 'teaching' not 'learning' A survey of first year students' expectations by Cook and Lackey (1999) found that freshers generally expected their learning experience would not differ greatly from secondary school. Today's students demand more than ever before: they expect courses to be fun to take part in and allow plenty of time for social interaction and revelry; they are increasingly driven by marks and reading appears to be a dying art. Furthermore, even a mild spell of disengagement can quickly lead to an unwelcome request for a course transfer.

Clearly, this does not sit well with the academic's need to convey large quantities of basic engineering science as the early building blocks of an engineering degree. Nor does it match the rose-tinted recollections of academics who cheerfully recall a mythical time when lecturers introduced a topic, students would copy large quantities of notes from the blackboard and work diligently through examples, then go home to read around the subject. When students don't respond and depart or fail, traditionalists are tempted to blame the students' lack of dedication or ability. This was the approach taken by Ozga and Sukhnandan (1997) in their model of non-completion using qualitative data from studies of UK institutions. They criticised many earlier attempts at explanatory models for focusing too much on the student; seeking faults in the students' behaviour to explain their withdrawal.

Loughborough's intake is predominantly traditional, typically three high grade GCE-A (Advanced) levels including Mathematics and physics and the vast majority are young school leavers. And despite many attempts to encourage women into engineering, most are male.

Since 2000, the A-level examination has been divided into a succession of six sequential modules causing the fragmentation of knowledge (Haywood and McNicholl, 2007), students describe an instrumental approach to learning where they gather marks from a collection of short term intensive assignments within the modules and the marks are all important to them. To achieve the best mark, students become very good at following instructions to the letter but there is little or no time given to any learning outside that directly associated with the instructions. Their teachers, who are very conscious of school league tables, naturally do little to discourage the mark culture and its knock-on effects. Furthermore, contemporary students arrive at university with the widespread belief that "the first year doesn't matter" which is the apparently logical but over-simplistic conclusion they draw because few UK universities carry first year marks into the final degree classification.

1.1 Practical Skills

Many have also observed that university intake is also massively short of practical skills and has little perception of how things work or what a career in engineering actually entails. As the world around us has changed, budding engineers no longer make their first associations with engineering at a young age by building models or repairing bicycles; processes that can help to sow the seeds of an enquiring mind and enable students to better understand the engineering world they have entered. Shobrook (2004) provided an extensive summary of the reasons for withdrawal from engineering programmes. The list was a long one but focused largely on the fact that student's pre-perceptions of engineering and engineering studies were not matched by the reality. She also pointed out that most entered university having studied maths and physics but had little real knowledge of what engineering is. At Loughborough, it was thought that this lack of the fundamental building blocks and the associated lack of an engineering vocabulary had also begun to inhibit the acquisition of higher level knowledge.

It was the realisation that young people are no longer the same and that universities need to adapt that drove the need for change. Surely, it is time to stop blaming the young people for the society we created and they live in.

2. ENGAGEMENT AND MOTIVATION

2.1 Engineering Principles and Professional Skills.

It is known that "…the adoption of teaching approaches that actively engage students from the outset" can enhance the student experience in transition (Yorke and Longden, 2008). These ideas are founded in constructivist learning theory where learners are invited to construct knowledge for themselves, become actively involved and learn how to learn while they are learning. This paper describes one successful experiment to address these issues.

A curriculum review panel, chaired by the lead author, decided to introduce a new year-long module alongside existing traditional engineering modules. The new module sought to exemplify fundamental engineering principles in a practical environment and help freshers acquire the necessary skills to become autonomous learners. Hence, it took the title Engineering Principles and Professional Skills (EPPS). High on the priority list was the need to actively engage the students: taking responsibility for their own learning, working creatively in complex situations and critical reflection are all characteristics of an autonomous learner. So, it was decided, the new module would be built around a variety of student-centred assignments of unequal length and complexity. The students would work together in teams formed around existing personal tutors.

Working with student feedback data collected over a number of years, the new module would replace existing material that was tired or outdated but retain and repackage elements that were proven to be working well alongside new problem-based material. While the new experiences were designed to improve fundamental knowledge and study competences they also provided the means to add considerable interest and enjoyment; furthermore, the informal staff-student interaction appears to be helping address the gulf in attitude to learning that previously existed between staff and students.

The new module includes 4 team projects and 6 skills workshops integrated together and supported by a short lecture programme. The team projects cover a wide range of topics and themes: competitive design, build and test, industry sponsored mechanical handling project, vehicle systems investigation and a start-up business game. The skills workshops include teambuilding, library skills, understanding learning styles, metrology and measurement, problem solving (robotics) and workshop skills. While this paper describes and reflects on only one of the team projects, PBL3 – 'vehicle systems investigation', it was always anticipated that success would depend on successful integration of all the elements alongside traditional study and the quest to establish a learning community with greater motivation and more autonomy.

2.2 The assignment.

The (PBL3) vehicle systems assignment starts immediately after the Christmas Vacation and lasts three weeks; that is, the student teams have three weeks to complete the work even though there are few timetabled events. This is the third scheduled group assignment of the year and by this time, the students are well rehearsed in working as a team and reporting to their 'personal tutor'. This project was created in academic year 2008/9 and ran a second time this year with a little refinement.

The intended learning outcomes for this assignment were:

- The ability to apply engineering principles in a practical situation through examples.
- Improved learner autonomy.
- Enhanced research, communication and team-working skills.

We needed a group of topics that were potentially interesting to mechanical engineers, complex enough to require significant understanding and with examples in abundant supply: the decision to focus on cars was, therefore, a simple one. A list of distinct ‘systems’ such as emission control, power brakes and active suspension were easily identified.

Such a research project would normally warrant students to submit a substantial written report and possibly an oral presentation. However, there was no requirement here to test these particular skills as they are already adequately assessed in other parts of the programme. The assessment process looked daunting: twenty four teams of freshers would tackle the project, some 150 students and the assessment task would inevitably fall on the module leader. Furthermore, compiling a written report was hardly going to motivate students. The present authors are indebted to Mike Brammall and his colleagues in Sheffield for providing the inspiration to try a new reporting and assessment method that was to become an integral and vital part of the assignment. Brammall et al (2008) demonstrated that video reporting provides an attractive medium for his final year materials students. They claimed that the video report added realism and aids communication and analysis skill; that students were motivated by this methodology and that it enhanced achievement. They also claimed that students developed a deeper understanding of the technical content of the exercise and that learner autonomy was developed although this was largely unproven.

During the introduction to the task, students were told that they must plan and schedule their own work. They should aim to become self reliant and that innovation and ingenuity is rewarded. Nevertheless they could ask for assistance through their personal tutors, the project leaders or the laboratory staff by making advance appointments. Several other help mechanisms were put in place, a web-based discussion forum, delivered by the university’s VLE, a Question and answer session timed one week from the start, the services of an Audio Visual Technician and some self teach materials appropriate for the project also mounted on the VLE. To ensure the teams headed off in the right direction at the outset, they were required to complete a pre-prepared ‘objectives’ form setting out their chosen topic, planned methodology and intended deliverables and discuss their plans with their team tutor.

2.3 Filming and Reporting.

Would first year engineers be able to direct, act, shoot and edit a watchable video documentary? – you bet they are. Students today have an expectation of using communication technologies. They "take them for granted and integrate them seamlessly into their daily lives. These technologies also represent an opportunity for making changes in higher education instruction. How can higher education fully embrace the possibilities they present?" (Caruso & Salaway, 2007) Easy creation, distribution and instantaneous uploading and downloading of digital media is the norm. 'MySpace' and 'YouTube' are just two examples of free user-generated online video sharing that are predominantly the preserve of the young. Over two years we have received 48 video reports and the baseline requirement of a filmed 10 minute presentation to camera has been exceeded in every case with some ingenious and relatively complicated screenplay.

Clearly, there is a requirement for equipment and this had to be supplied with a limited budget. Six kits were bought specifically for the job, each kit comprised a hard drive video camera, an inexpensive tripod, a hand held microphone for narration and a carry bag and the total cost was under £2000. Teams loan camera kits for 48 hour periods against a returnable deposit. It would be helpful to add a couple more kits when finance permits. The inexpensive equipment is easy to use and adequate for the task; the only real deficiency is the lack of provision to connect an external microphone to the camera, a feature that is only available on more expensive cameras. For video editing, we use Windows Movie Maker, which is included on all Windows lab computers at no cost.

No formal training in filming or video editing was either provided or necessary save for a short list of ‘dos and don’ts’ and some general advice during the introduction. Revealing sample clips this year appeared to promote extra enthusiasm for what, at first appears to be a considerable challenge. I need not have feared that the students would rise to the challenge. Some teams were keen to integrate humour into their serious research and this was encouraged, as it would help to promote engagement. Nevertheless, the assessment criteria, published in advance were weighted towards the demonstration of knowledge and understanding of the vehicle system.

Filming took place in a variety of locations of the students choosing; in labs and workshops, in halls and student houses, in group study rooms and on location in their own and sometimes their tutors’ cars. Some students headed for the local scrap yard in search of relevant artefacts to dissect while others headed off to interview the local dealership and found them surprisingly accommodating.

Of course, a lot of research involved the library and the internet and this enabled us to convey, in sharp focus, the rules of copyright. All teams were required to submit, with their video, a release form allowing the module leader to make use of the media together with a declaration of the copyright status of all materials used. Teams were encouraged to use copyright free or Creative Commons licensed materials although copyright protected material can legally be used for personal research and educational purposes. It should be noted that videos containing copyright media, sound or pictures, cannot be publicly shown.

An added bonus of video reports is the opportunity to use them as a future learning media resource. Selective use of a 10-minute student made documentary video or edited highlights of it can add spice and interest to the lecture programme and disseminates research on the wide variety of topics throughout the whole group.

2.4 Assessment.

The assessment and feedback task was straightforward and, for once, quite enjoyable. Two staff members watched each documentary at the same time and independently rated it against fixed criteria. *Structure. Evidence of teamwork, technical content; breadth depth and accuracy, audience engagement; clarity & impact, and innovation.* Grades associated with the School’s generic grade descriptor assessment policy using terms like ‘outstanding, good and weak’ were used to assign grades against each criteria, and these were later computed into an overall numeric score. Feedback was provided in the form of a table of comments against each criterion. Assessing 24- 10 minute videos equated to one day’s work for two people.

3. STUDENT SURVEY

Students in 2009/10 were asked to complete an online questionnaire following the Vehicle Systems project. A broad range of questions covered team working practices, experience of working with their personal tutor, how they interacted to complete the task, and their reflections on the experience. Data was collected from individual students with a response rate of 51%. The questionnaires gathered both quantitative and qualitative data. A thematic analysis was used to analyse the qualitative data. There were 24 teams each with 5 or 6 students.

3.1 *Quantitative results.*

Summarising the quantitative data; several questions investigated the level of engagement and motivation brought about by the activity. 84% of respondents stated that the topic, chosen by the team was their first choice and 76% reported that they had **enjoyed** the task. Enquiring about community spirit, students were asked to rate how helpful they'd found their personal tutor in the PBL3 Video project. 72% responded positively to this question with nearly 10% describing their personal tutor as being 'enthusiastically helpful'. Prior to the initiative the longstanding personal tutoring scheme had been patchy, at best. 84% claimed to have met together as a team more than once each week of the task.

Using a 5-point Likert scale, students were asked whether they thought this assignment was an effective learning tool: 87% felt that they had **learnt or consolidated knowledge** of engineering principles by completing the task. 80% felt that the project was effective for improving **transferable skills** such as researching, communication or IT skills. Figure 1 illustrates these results graphically.

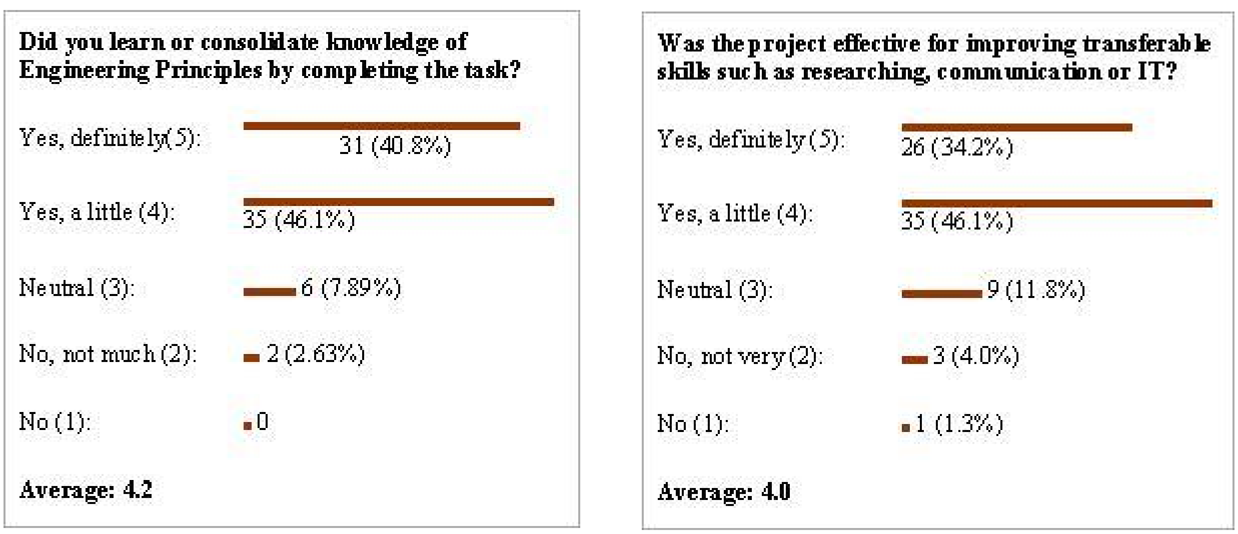

Figure 1: Perceived effectiveness, (a) acquisition of knowledge and (b) skills development

3.2 Thematic analysis.

Students were asked to comment freely about what was best about this project. Responses tended to relate to one or more of seven themes.

- The learning experience
- Doing something different

- The team aspect
- Technical knowledge
- Freedom
- Fun
- Filming the video

In particular, twenty students made positive comments relating to the **video reporting** aspect of the learning experience, for example; “Written reports can easily be ‘blagged’ by finding information on the internet and compiling it into a neat and tidy work document, but the video report forces you to take a deeper look into the subject”. They welcomed “the opportunity to talk to experts…and the need to find our own props” [*for the film*]. “Being creative in showing a subject of engineering”; “It made me think in different ways due to the new format of presenting information”.

A common theme amongst comments on the learning experience was their appreciation of being able to do something ‘**different**’. For example; eight students made a specific comment on this aspect. “The self satisfaction of doing something different other than writing a report or doing an exam”. “It was a nice change from the norm”. “It was very different”. “Doing something different to labs and lectures”. “It was just nice to do something different for a change”.

Thirteen students referred positively to the **team aspect** of the project. Students appreciated being able to “work as a team” and comments suggest that they felt that the project had enabled them to “bond as a team”. One elaborated; “It [*the assignment*] allowed team dynamics to really flourish, highlighting everybody’s role in the team well, which should prepare us better for the major project PBL4”. Another respondent commented, “teaching you to work better as a team and become better friends as a result.”

Thirteen students valued the **technical knowledge** developed through the project. Comments included: “Learning about the engineering behind a system and how our study relates”. “Discovering new information about the working of each component to add to my previous knowledge”. “Actually learning about how a hybrid vehicle works, it was very interesting.”
“We get to know how safety systems work in a car and the importance of it! How through equations of physics and creativity we can improve the mechanisms!”

Twelve students highlighted ‘**freedom**’ as one of the best aspects of the project. Comments either referred to the fact that they could choose their topic or freedom in how they tackled the project. Typical comments included: “Freedom to plan and put together the video by ourselves when and how we want”. “The fact that the topic could be chosen”.

Eight students made comments on the **fun element** of the project. The typical comment on this was that “it was fun”. More expansive responses included. “A very enjoyable task”, “it was more entertaining than sitting down for an exam”.

Seven positive comments were made relating to the **filming of the video**. Two comments in particular attributed learning new skills and improved team relations to the filming process itself.

4. DISCUSSION AND CONCLUSIONS

There was a good feeling about this assignment; as though we had something right with the vast majority of students appearing ‘on-side’. Informal reports from personal tutors who were ‘roped in’ by their tutees were also enthusiastic in the main. Furthermore the evidence from the online survey is encouraging. We speculate that few conventional coursework assignments would prompt a response from 3 in 4 students that they had enjoyed completing it.

Although the questionnaire did not explore changes in attitude to learning, respondents positive perceptions of the video project in terms of engaging with their personal tutor and tutor group, valuing the opportunity to choose their topic of study, and engaging in an assessment method that they perceived to be both fun and a means of broadening their skills. One particular telling comment hints at a positive change in attitude. “The project was educative and fun at the same time – which is rare and I believe my lab partners and I seized the opportunity to work together better.” The survey data also demonstrated considerable success in achieving the outcomes of improved knowledge and transferable skills; at least, this was the students’ perception.

This adventure has proved interesting and instructive for both staff and students. An assignment like this will not, in itself remedy all the problems of engagement and transition to university but as part of a planned programme of activities it just might. The survey suggests that for this assignment at least and by implication, the ethos of the new EPPS module have been successful in meeting their objectives. Whether this translates into reduced wastage rates remains to be seen.

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TEACHING SUSTAINABILITY THROUGH CATALYSIS

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Abstract: Catalysis is the essential chemical phenomenon that underlies all living systems, and is key to creating sustainable processes and a greener environment (Armor 1999, Centi 2008). Catalysts accelerate chemical reactions, and efficiently channel energy into building complex molecular structures. Catalyst's ability to perform specific reactions with great precision through millions of cycles is the basis of sustainable processes. Thus the concepts of sustainability can be clearly illustrated using examples of natural and manmade catalytic processes.

Natural catalytic cycles, such as the photosynthetic production of carbohydrates, are made possible through enzymes. The efficient conversion of oil, gas, coal and biomass into fuels and chemicals is made possible by modern catalytic technology. In this discussion, the catalytic cycle is presented to facilitate the discussion of sustainability. Catalysis can be used to address some of the key problems facing the 21st century; in particular the production of fuels and chemicals in absence of petroleum is discussed here as an example.

On the cutting-edge of catalysis research is the Temporal Analysis of Products (TAP) reactor system. The TAP technique is a unique tool for capturing kinetic features (e.g. rates of transformation and energetic properties) of the fundamental molecular transformations occurring on catalytic surfaces. These experiments promote inquiry based learning where the outcome of one experiment will determine the conditions for setting up the next. This demonstration of the catalytic cycle in action will reinforce classroom learning of sustainable processes.

Keywords: catalysis, sustainability, TAP reactor, catalytic cycles, internet experiments, engineering education.

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1. INTRODUCTION

1.1 Catalysis and Sustainability

As tomorrow's scientists and engineers take on the challenges of pollution, climate change and energy needs, the interdisciplinary nature of the environment, human health and the systems that support our modern life will require that their choices in the development of new technologies be made within the framework of sustainability. Taking the example of catalysis and catalytic transformations can be used to integrate the principles of sustainability in the curriculum learning. Catalysts play a key role in improving and maintaining air, water and soil quality and are central to the production of fuels, food, chemicals and pharmaceuticals. The program described here captures the central role of catalysis as an enabling science to instill the ideals of sustainability in the next generation of entrepreneurs, educators, scientists and professionals.

2. NATURAL CATALYTIC PHENOMENA

The complexity of natural cycles such as the geophysical carbon, water and nitrogen cycles provide an excellent starting point for describing the natural basis of sustainable processes. Although they are global in scale, the action of these processes are evident in everyday life and thus more relevant to the student. Observation of these phenomena outside of the classroom will strengthen the student's understanding of how the natural systems in place are inherently sustainable. The chemical processes of photosynthesis and the conversion of these carbohydrates into energy output and material substance in the animal species are two mechanisms relying on biocatalysts or enzymes. These cyclical processes are depicted in Fig. 1.

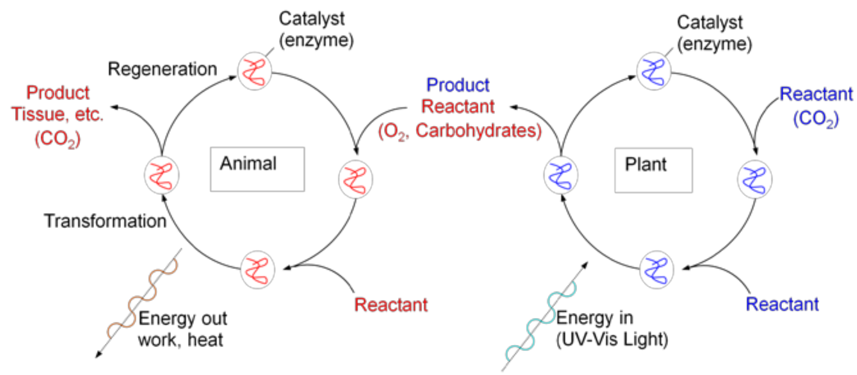

Figure 1. Coupled Catalytic Cycles - The natural basis of sustainable processes.

Explaining the earth's natural process in terms of these coupled catalytic cycles can also help to emphasize the consequences when human activity disturbs these often delicately balanced processes. Prior to the industrial revolution man's impact on the environment was insignificant. With the discovery of new fuels and chemical process for making materials a modern way of life emerged. At first little attention was paid to the efficiency or waste since fuels and raw materials were abundant. As the scale of these processes increased along with the explosion of population growth the consequences of irresponsible consumer and industrial practices are now clearly apparent with repercussions throughout the environment, economy and social fabric. The solution to making most industrial processes more efficient, less wasteful, more environmentally benign and more economical are to employ catalysts; this philosophy is the basis of sustainability.

3. THE CATALYTIC CYCLE

A catalyst facilitates a molecular transformation that would otherwise proceed at a very slow rate. A chemical reaction may be thermodynamically possible but too slow to be useful. For example, many of the transformations we pursue for the production of fuels and chemicals are readily performed in biological systems; and at ambient conditions. In nature, enzymes easily convert methane and CO_2 to functionalized products (alcohols, sugars and carboxylic acids). For example, methantropic bacteria containing an enzyme methane monooxygenase, will selectively produce methanol from methane and oxygen at ambient conditions using an iron center (Labinger 2004). In the laboratory, efficient catalytic conversion of methane to higher order oxygenates remains a major unsolved scientific challenge. These reactions are thermodynamically possible but presently there are no catalytic materials available for an efficient and economic process. Perhaps the biggest impediment is the energy required to activate methane's very stable C-H bond (425 kJ/mol), a much stronger bond than any potential products. Thus products are more reactive and selectivity suffers if thermal routes alone are employed.

The comparison is not entirely fair however amongst biocatalytic (enzymes), homogeneous (atomic, molecular, and metal complexes), and heterogeneous (simple or complex solids) processes. Enzymatic processes offer precise control and selectivity but lower rates. For example, the absolute rate of an industrial catalytic process is typically 100 times higher than that of a biochemical process (Grima 2009). Classical descriptions of enzyme kinetics typically do not include the role of transport in the intracellular environment which slows the observed rate of the process. Homogeneous processes offer superior selectivity while heterogeneous catalytic processes are useful in controlling heat transfer, minimize the use and need to separate solvents, and often generate less by products.

The generic catalytic cycle is depicted in figure 2. The catalyst in state 1 (for example an oxidized state) adsorbs molecules A and B on the surface. With the application of energy, either thermal or radiative, reaction occurs and products C and D are formed. The goal is to find a catalyst that maximizes the amount of the desired product and minimizes waste products but without sacrificing the rate of reaction where the process would no longer be economical. During the reaction step the catalyst may supply electrons and thus be rendered to a reduced state. Regeneration of the catalyst through oxidation then completes the cycle and the catalyst can be reused. The catalyst offers precise spatial and temporal control of chemical reactions, can operate billions of cycles and performs the storage and release of energy.

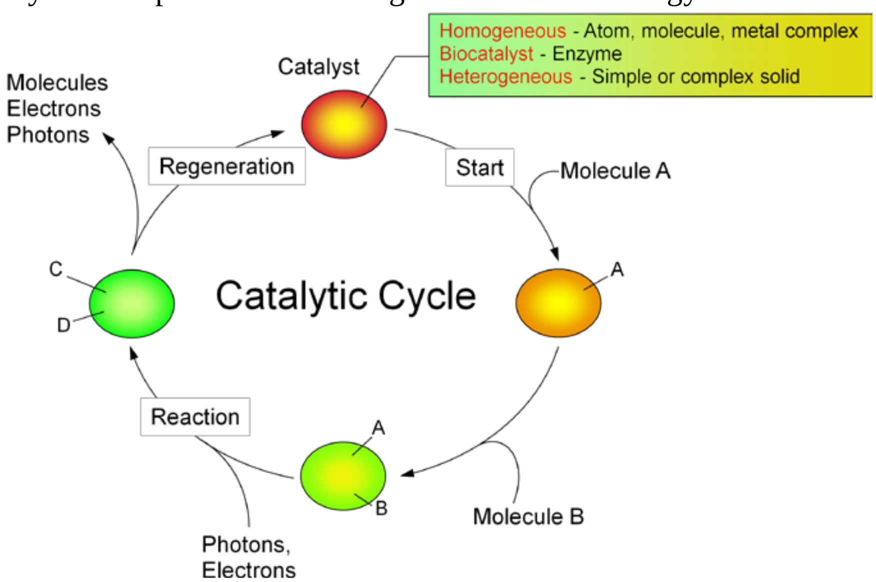

Figure 2: A generic catalytic cycle.

Engineers aim to design processes that mimic the complete catalytic cycle as closely as possible. In reality however the catalytic materials and reaction technologies are not ideal. With the demonstration of catalytic technologies used on an industrial level, students can examine the consequences of shortcomings at each step of the cycle. For chemical engineering students, the chemistry and reactor engineering (mass balance, materials contacting, heat transfer, etc.) are part of the core curriculum learning. Students however are less often introduced to the extraneous processes that support these operations and the consequences of deviations from ideality. If we examine the catalytic cycle with the ideals of sustainability in mind we must consider first where the reactants come from, how much energy is needed to extract and purify them, what is the impact on the economy, environment and social stability of the locale producing these raw materials? The environmental fate of the raw materials can be presented in the form of a life cycle analysis and generally will demonstrate the interconnectedness of engineered systems with the environment, economy and social fabric. Catalysts in particular are often composed of rare earth and noble metals, the mining of which can be very damaging to the environment.

Now that the scale of industrial processes has highlighted the limits of raw materials available the engineering must consider if reactants A and B are not completely adsorbed on the catalyst surface the reactor feed may be recycled. Even recycling requires separation prior to reintroduction to prevent dilution of the reactant stream. At what point does feed recycling no longer have an economic advantage? What might be the result of having unreacted reactants in the product stream?

Many advances in efficiency can be made in the supply of energy to the reaction. The student must consider the processes that go into producing electricity, thermal oxidation or other alternative heat sources. Different modes of heat transfer can be evaluated for their benefit to energy efficiency but also one must consider their effect on catalytic performance. Heat integration from other parts of the process should be considered. Equally important is the consideration of the cost of cooling a process; what is the fate of the waste heat? This can be made as another example of life cycle analysis.

The catalytic material must be designed to maximize the production of selective products but not at the expense of the reaction rate. Students can examine the tradeoff between separation of byproducts and loss of reaction rate. What will become of the byproducts; disposal, thermal oxidation or use in another process? What is the cost of regenerating the catalyst after reaction? What are the advantages to using air as opposed to pure oxygen? How many cycles can the catalyst perform? Students can examine the consequences of catalyst deactivation due to incomplete reaction (e.g. coking), trace impurities in the feed stream (e.g. poisoning due to sulphur) and sintering at high temperatures.

A case study of several different industrial processes will highlight all of these deviations from the ideal catalytic cycle and help students to understand that the needs of designing sustainable processes go much further than maximizing product yield. Examples of catalytic processes in place that would be useful include the production of maleic anhydride from butane over the VPO catalyst, auto-exhaust catalysis, fuel cell catalysis, and the production of nylon, L-dopa and aspartame. From these examples of catalytic processes, students can calculate estimates of the ecological footprint for producing these materials.

Some of the technological problems scientists and engineers are now working on should be introduced for open-ended discussion. Suggestions include:

1) Manufacturing fuels and chemicals from alternative sources, this topic expanded in the next section as an example.
2) CO_2 capture and large scale conversion to CO, CO conversion to fuels and chemicals using Fischer-Tropsch chemistry,
3) Hydrogen production in fuel cells with on-board reforming of ethanol,

4) Enzymatic conversion versus catalytic reforming of biomass for the production of ethanol,
5) Catalysis for mitigating radioactive pollutants, mercury, sulfur dioxide, and nitrogen oxides in coal processing, clean coal technology for reduction of CO_2 emissions.

The reader is referred to several articles that highlight the importance of catalysis for creating sustainable solutions to today's environmental and energy challenges (Armor 1999, Centi 2008, Vlachos 2010). Key drivers for invention of new catalysts include the development of advanced materials and more efficient processes with negligible emissions and a reduced environmental footprint. New technology to replace existing outdated processes must be safer, produce negligible emissions, require lower capital, and demonstrate a lower cost of manufacturing. These projects are still open-ended and will be the challenges that today's student will take on after their studies. Introducing these problems now is useful to help students envision their role in providing tomorrow's solutions.

4. EXAMPLE DISCUSSION

4.1 Beyond petroleum, manufacturing fuels and chemicals from small molecules

Current world oil consumption is 80 million barrels a day, and at this rate the proven world oil reserves will be depleted in 40 years (Davis 2003). Today's consumption rate is more than 8 times the 1950 rate, and is expected to grow to at least a 120 million barrels a day by 2025 (Davis 2003). As oil reserves decline, natural gas will begin to replace oil as the major feedstock for fuels and industrial chemicals. During the period of decrease the demand for oil will exceed the rate of production (Gai 2003). By 2050 it is projected that the world population will reach 9 to 10 billion (Fontes 2002), and current reserves of both oil and natural gas will be exhausted (Davis 2003).

How to supply the vast quantities of fuels and chemicals when oil is no longer readily available is one of the most challenging and important problems now facing humanity. Students should consider the consequences that come with each alternative feedstock. For example, at present, natural gas and coal are the only viable alternatives to oil, but reserves are also finite. Like oil, burning gas or coal emits CO_2 (a greenhouse gas). At current rates of production, the CO_2 concentration will more than double the preindustrial concentration by 2050 (Bradley 2004). Coal burning also produces radioactive pollutants, mercury, sulfur dioxide, and nitrogen oxides. Biomass is the only renewable, emissions neutral source of carbon, and hydrogen (produced from sunlight) the only renewable carbon-free energy carrier. The long-term solution to the problems of dwindling oil and gas resources and global warming is switching to these renewable sources. However, regardless which feedstock (natural gas, coal, or biomass) is used, there are currently no economically viable processes for producing many of the materials now obtained from oil. For the next-generation the development of efficient, economical, and environmentally benign processes for producing fuels and chemicals from gas, coal, and biomass will have a tremendous societal impact.

Current developments in catalytic technology are aimed at addressing these concerns. This topic presents an excellent opportunity for students to carry out a research report. After researching a specific catalytic technology addressing this issue students may present their evaluation of the sustainability of the approach. For example, the synthesis of liquid fuels and chemicals from natural gas or coal starts with the direct conversion of CH_4, or the production of synthesis gas (aka syngas), a mixture of CO and H_2 (Holmen 2009, Vora 2009). Fischer-Tropsch synthesis is currently used on the industrial scale to convert syngas to long-chain hydrocarbons, aka the gas to liquids (GTL) process (Schanke 2004). With the current technology, more than

60% of the capital costs of GTL plants arises from the energy intensive reforming of methane (Holmen 2009). An enormous economic impact could be made if current efforts in reforming catalyst technology are successful. Even though methane and coal resources are more plentiful than petroleum, their use results in a net positive addition of carbon to the atmosphere.

Many of these issues can serve as a starting point for research and discussion amongst students. Learning the example of a catalytic process will reinforce the ideals of sustainability. More importantly, participation in the cutting-edge of catalysis research will motivate and empower students with the skills to take on these challenges.

5. TAP REACTOR STUDIES OF CATALYTIC PROCESSES

Following the lecture-based and research-based case studies, the project can culminate with students participating in cutting-edge catalysis research by performing long-distance experiments using the Temporal Analysis of Products (TAP) reactor system, described in the next section. One benefit of using the TAP reactor system is the execution and analysis of experiments can be demonstrated during a lecture using a remote automation feature of the TAP automation and control software.

5.1 TAP experiment and theory

The TAP reactor provides a unique method for characterizing heterogeneous catalytic reactions using realistic catalytic materials (Gleaves 1988, 1997, 2010). Figure 3 depicts the TAP reactor system. The catalysts particles are packed in a thin layer between two zones of inert material. The microreactor is heated and a thermocouple monitors the catalyst bed temperatures. The reactor is continuously pumped by an oil diffusion pump with a liquid nitrogen cryotrap to maintain ultra high vacuum conditions (pressure $\approx 10^{-9}$ torr). A small pulse of molecules is injected into the evacuated reactor and the gas molecules travel the reactor via Knudsen diffusion. That is to say there is no plug flow and the concentration is low enough so that molecules are not influenced by collisions with other molecules in the gas phase. The narrow pulse of molecules injected into the reactor will naturally diffuse through the reactor packing and interact with the catalyst particles resulting in a broadening of the pulse shape as seen at the exit of the reactor. Thus the diffusion is well defined and any time delay of the molecules exiting the reactor can be attributed to kinetic processes occurring on the catalyst surface. The exit flow of the product or reactant molecules is monitored by a quadrupole mass spectrometer directly beneath the exit of the microreactor.

5.2 Real time experiments over the internet

One feature recently developed in the TAP system is the ability to perform real-time experiments remotely using special software and an internet connection (Fushimi 2010). Integrating this feature into the research equipment makes state-of-the-art science available to students and makes this program easily portable to other institutions. A TAP pulse response experiment is very fast, usually between 1 and 10 seconds. This makes the remote demonstration of the experiment possible during a classroom lecture. To perform an experiment the catalyst must first be loaded manually by an operator. The lecturer can then, from a remote site, increase the temperature and begin pulsed experiments. After quickly calculating the conversion with the help of a ready-made analysis algorithm, the experiment conditions may be changed, either temperature, pulse size or reactant molecules (e.g. oxygen as opposed to a hydrocarbon). In this manner, conversion and selectivity data could be quickly complied at several temperatures in one hour’s time. Students could use this data to calculate a first order

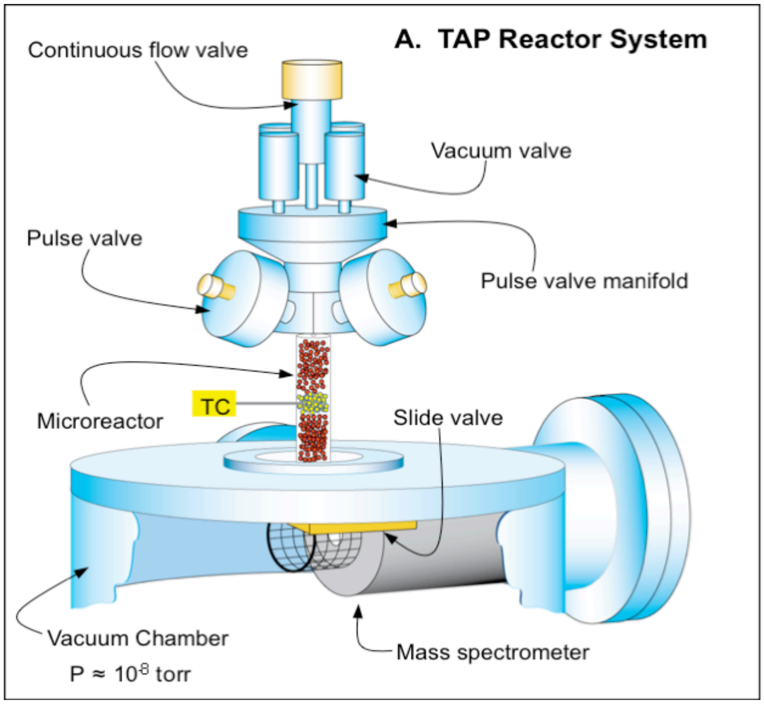

Figure 3. Simplified schematic of the TAP reactor.

reaction rate constant, $x/(1-x)$, where x represents conversion, followed by construction of an Arrhenius plot to determine activation energy. This simple demonstration will create a clear impression on students the meaning behind the rate constant and activation energy. The chemistry and catalysts used will show how the clever engineering of materials can lead to more efficient molecular transformations.

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